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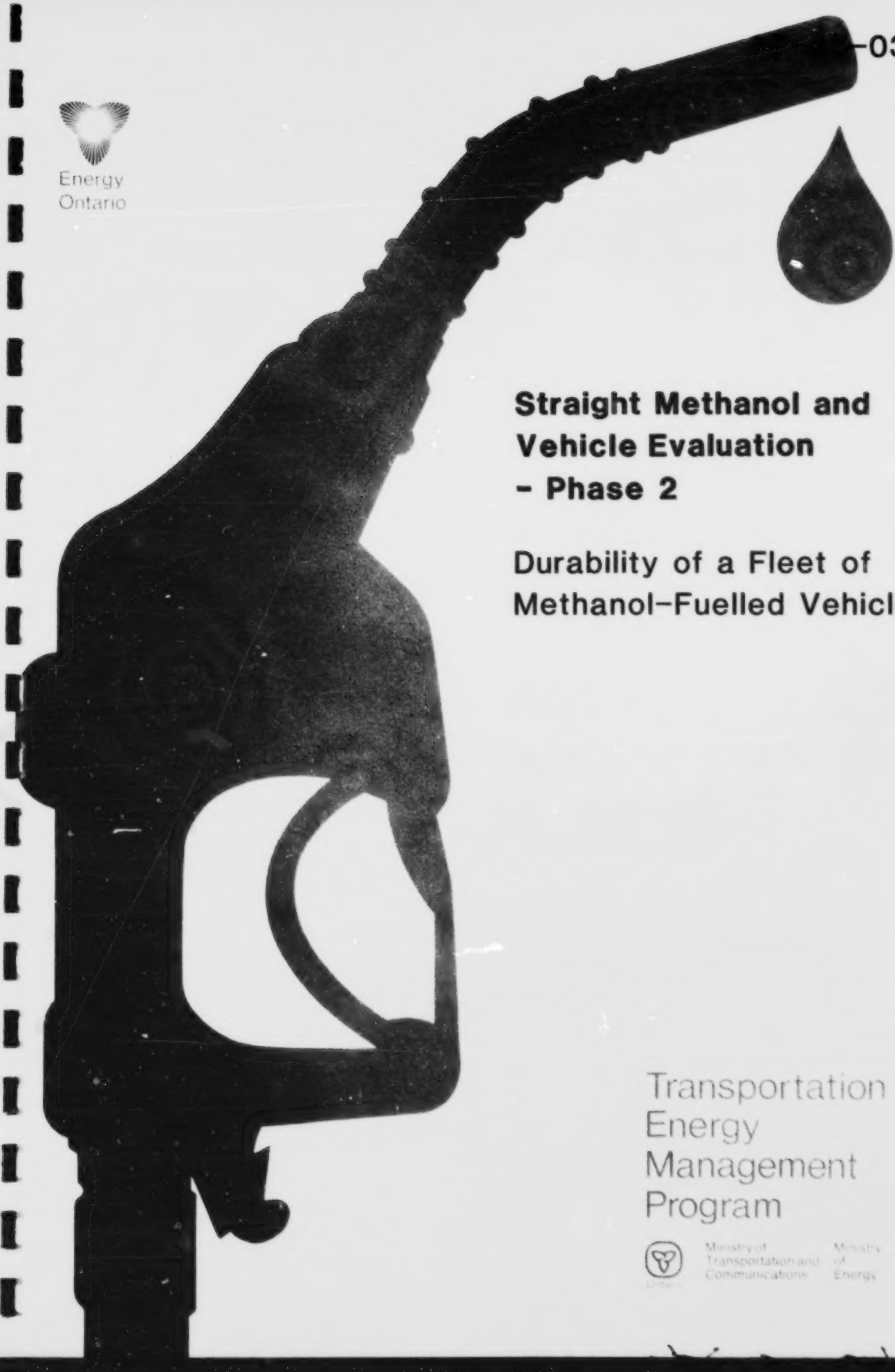

Straight Methanol and Vehicle Evaluation - Phase 2

Durability of a Fleet of Methanol-Fuelled Vehicles

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1/ INTRODUCTION

Methanol is seen, by some, as a viable future fuel for internal combustion engines in Canada. Shell Canada, in association with Ford of Canada Ltd., has operated a small fleet of 1983 Ford Escorts specifically built to operate on near-neat methanol fuel, for a period of approximately one-and-a-half years.

This program was partially financed by both the provincial and federal governments under the Transportation Energy Management Program (TEMP), administered by the Ministry of Transportation and Communications and the Ministry of Energy in Ontario.

This research project is Phase 2 of a program started early in 1983. Phase 1 of the program addressed problems with cold weather operation of these methanol-fuelled vehicles. Phase 2 addresses the durability aspects of methanol-fuelled vehicles via a longer term fleet test under typical Canadian climatic conditions. These long-term test results for a fleet of near-neat methanol-fuelled 1983 Ford Escorts are detailed in this report.

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Abstract:
A fleet of Ford Escort vehicles designed to run on methanol has been evaluated under a program of short- and long-distance accumulation, using appropriately designed fuel and oil formulations. Durability was checked by detailed measurements of the stripped down engine components at the beginning and end of the test period. This was supplemented by regular sampling and analysis of the engine oils used by the vehicles. On-the-road fuel consumption of the fleet was monitored, and operational problems, including those of the fuel dispensing system, were recorded and remedied where possible. Cold weather driveability was examined on selected vehicles, and some were tested on the chassis dynamometer for fuel consumption and exhaust emissions.

Key Words: methanol-fuelled vehicles, engine durability, lubricants, cold weather performance

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ABSTRACT

A fleet of Ford Escort vehicles designed to run on methanol has been evaluated under a program of short- and long-distance accumulation, using appropriately designed fuel and oil formulations. Durability was checked by detailed measurements of the stripped down engine components at the beginning and end of the test period. This was supplemented by regular sampling and analysis of the engine oils used by the vehicles. On-the-road fuel consumption of the fleet was monitored, and operational problems, including those of the fuel dispensing system, were recorded and remedied where possible. Cold weather driveability was examined on selected vehicles, and some were tested on the chassis dynamometer for fuel consumption and exhaust emissions.

RÉSUMÉ

Un parc de véhicules Ford Escort à moteur à méthanol a été mis à l'essai; pour obtenir un kilométrage suffisant, certains ont été conduits sur de petites distances alors que d'autres ont effectué de longs parcours; le carburant et l'huile appropriés ont été employés. Pour déterminer la durabilité du moteur, on en a mesuré les pièces démontées avant et après l'essai. On a de plus prélevé et anlysé régulièrement l'huile des moteurs. Dans des conditions de conduite ordinaire, on a mesuré la consommation de carburant du parc et observé les problèmes de fonctionnement, y compris ceux provenant du système d'alimentation en carburant; des mesures correctives ont été prises lorsque cela était possible. La conduite par temps froid a été étudiée sur des véhicules sélectionnés, et on a mesuré la consommation de carburant et les émissions de polluants au moyen d'un dynamomètre de châssis.

EXECUTIVE SUMMARY

This project represents the second phase in the performance evaluation of factory-built Ford Escort vehicles designed to run on methanol. Following the first phase, in which special fuel mixtures were developed to aid cold startability, the vehicles were placed in fleet operation to accumulate distance to assess operational problems and engine durability. Oil formulations were made up by Shell to counter expected corrosion problems caused by methanol use. Some of the vehicles were run in a short-distance accumulation mode, which is particularly severe with respect to engine life; others were run in a longer distance mode. Two vehicle engines from each group were initially stripped down and measured in detail and then remeasured at the end of the term to determine component wear directly. Regular sampling and analysis of the oil of all the vehicles was also carried out to supplement the durability assessment. The overall conclusion was that engine life would be diminished under more severe driving conditions relative to gasoline experience and that further development of oil formulations was warranted.

Some of the vehicles were tested for cold weather driveability, and for fuel consumption and emissions on the chassis dynamometer. Cold weather driveablity was deemed unacceptable by gasoline vehicle standards, which suggests the need for some recalibration. Fuel consumption was also greater than expected at low temperatures. Emissions were satisfactory according to Canadian standards; however, there was some evidence of catalyst deterioration over time.

During the test program, operational problems, including those involving the fuel dispensing system, were monitored. Contamination and component degradation were noted and corrective action taken.

The project points to the need for further development work in lubricants and engine recalibration.

RÉSUMÉ

Cet essai constitue la seconde phase de l'évaluation du comportement de véhicules de série Ford Escort à moteur à méthanol. À la suite de la première phase, durant laquelle des mélanges spéciaux de carburants ont été mis au point pour améliorer le démarrage à froid, les véhicules ont été incorporés dans un parc afin qu'ils accumulent un kilométrage suffisant permettant d'évaluer les problèmes de fonctionnement et la durabilité du moteur. La compagnie Shell a mis au point plusieurs formules d'huile pour neutraliser les effets prévus de la corrosion due au méthanol. Certains véhicules ont parcouru de courtes distances successives, mode de conduite qui réduit considérablement la durée utile d'un moteur, alors que d'autres ont effectué de longs parcours. On a démonté deux moteurs de chacun des groupes de véhicules et mesuré minutieusement chaque pièce avant et après l'essai; cette méthode permet de déterminer directement l'usure de chaque élément. On a aussi régulièrement prélevé et analysé l'huile de tous les véhicules pour obtenir des données supplémentaires à l'évaluation du comportement. On est parvenu à la conclusion générale que, dans les conditions de conduite les plus dures, la durée utile du moteur est inférieure aux résultats obtenus avec un moteur à essence et qu'il y avait lieu de continuer à mettre au point des huiles à moteur.

Certains des véhicules ont été mis à l'essai pour juger de leur comportement par temps froid; on a en même temps mesuré la consommation de carburant et les émissions polluantes au moyen d'un dynamomètre de châssis. Par rapport aux normes applicables aux moteurs à essence, les résultats obtenus avec ces véhicules ont été jugés inacceptables, ce qui indique que le recalibrage de certaines pièces du moteur s'impose. En outre, à basse température, la consommation de carburant est plus élevée que prévue. Le taux des émissions de polluants, selon les normes canadiennes, est satisfaisant, toutefois, on a observé qu'à la longue le catalyseur se détériorait.

Durant l'essai, on a surveillé les problèmes de fonctionnement y compris ceux provenant du système d'alimentation en carburant. La contamination et la dégradation des éléments sont manifestes et des mesures correctives ont été prises.

L'essai indique clairement la nécessité d'une mise au point plus précise des lubrifiants et celle du recalibrage du moteur.

1/ INTRODUCTION

Methanol is seen, by some, as a viable future fuel for internal combustion engines in Canada. Shell Canada, in association with Ford of Canada Ltd., has operated a small fleet of 1983 Ford Escorts specifically built to operate on near-neat methanol fuel, for a period of approximately one-and-a-half years.

This program was partially financed by both the provincial and federal governments under the Transportation Energy Management Program (TEMP), administered by the Ministry of Transportation and Communications and the Ministry of Energy in Ontario.

This research project is Phase 2 of a program started early in 1983. Phase 1 of the program addressed problems with cold weather operation of these methanol-fuelled vehicles. Phase 2 addresses the durability aspects of methanol-fuelled vehicles via a longer term fleet test under typical Canadian climatic conditions. These long-term test results for a fleet of near-neat methanol-fuelled 1983 Ford Escorts are detailed in this report.

2/ TEST METHODS

2.1/ Test Cars

The test vehicles in the fleet were 1983 Ford Escorts developed by the Ford Motor Company to operate on a blend of 90% by volume methanol and 10% by volume winter grade non-leaded gasoline. These vehicles were developed by Ford to operate in government service in California.

The cars were calibrated to meet 1983 California emission standards. The emission standards are 0.39 g hydrocarbon (HC)/mi (non-methane standard), 7.0 g carbon monoxide (CO)/mi and 0.7 g nitrogen oxides (NO_x)/mi, or 0.24 g HC/km, 4.3 g CO/km, and 0.43 g NO_x/km.

The test car specifications are given in Table 1. Eight vehicles were operated by Shell and eight by Ford of Canada Ltd. (Appendix A).

2.2/ Test Fuels

The test fuel used varied over the test. Based on the results of Phase 1 [1], a blend of 90% by volume methanol and 10% by volume super non-leaded gasoline was specified for use during the summer months. With up to 6% by mass dimethyl ether (DME) added, this blend was specified for use during the winter months.

Seven different blends were used between July 1983 and November 1984. Table 2 lists the blend specifications and inspection properties. Table 3 details the base component properties.

The variations in fuel properties, namely, energy content and volatility, were expected to impact the fuel consumption of the test cars.

The test fuel blends were stored in 1000 gal (Imp) stainless steel tanks at both Ford and Shell locations. Dispensing system problems are discussed later.

2.3/ Test Parameters

The major concern in Phase 2 was the durability of these methanol-fuelled vehicles under typical Canadian climatic conditions.

The program was designed to evaluate the following:

- operational problems due to the use of near-neat methanol fuel;
- maintenance problems due to the use of near-neat methanol fuel;
- fuel consumption of these near-neat methanol-fuelled vehicles;
- engine durability via pre- and post-test engine component measurements and used-oil analysis;
- fuel dispensing system durability;
- other technical evaluations -- cold weather driveability and fuel consumption and exhaust emissions to Transport Canada standards.

2.4/ Test Configuration

The eight cars at Shell were split into two groups -- four cars were operated in "Aunt Minnie" service and four in normal fleet service. Aunt Minnie service is defined as short trip (less than 10 to 15 km) driving under low ambient temperatures. The normal fleet service was defined as approximately 30% urban/70% highway driving. All kilometre accumulation was via employee use of the cars both during and outside working hours.

Of the Ford of Canada vehicles, three had atypical operational experience because of their use in the earlier cold-start tests; these were sent to Dearborn for experimental work to devise a recalibration procedure for the next phase of the program. The remaining five cars were operated by specific employees in general service, as part of Ford's employee lease program, and their results are included in this report.

Four of the eight cars at Shell, two in each service group, were pre-measured. The pre-measured components included the following:

- cylinder bore diameter, both longitudinal and transverse, at three locations -- the top, middle and bottom of the ring travel region (four sets);
- piston skirt diameter (four);
- ring gap, top and middle rings (four sets);

- ring weight, top and middle rings (four sets);
- rod bearing weights (four sets);
- main bearing weights (five sets);
- ring side clearances, top and middle rings (four sets);
- valve lifter heights, intake and exhaust (four sets);
- valve stem diameter, intake and exhaust (four sets);
- valve guide internal diameter, intake and exhaust (four sets);
- valve tip height, intake and exhaust (four sets);
- camshaft lobe heights, intake and exhaust (four sets);
- rocker arm weights (four sets);
- rocker arm pivot weights (four sets);
- valve weights (four sets);
- main bearing journal diameters, horizontal and vertical (five sets);
- connecting rod journal diameters, horizontal and vertical, (four sets).

All eight Shell cars were rated at the end of test for the following:

- sludge deposits - rocker arm cover
  - front seal housing
  - oil pan
  - valve deck area
  - block underside
- varnish deposits - piston skirts
  - rocker arm cover
  - cylinder wall (below ring travel)
  - oil pan
- stuck components - rings, lash adjusters
- clogging - oil rings, oil screens
- valve deposits

All the above were rated by Co-ordinating Research Council (CRC) methods.

Used-oil analysis was also used to monitor engine durability. The Aunt Minnie cars had their oil sampled and tested at 1000, 1500, 2000, 2500, 3000, 3500 and 4000 nominal kilometre readings. The normal-service cars had their oil sampled and tested at 1000, 2000, 3000, 4000, 5000, 6000,

11 000, 16 000, 21 000 and 26 000 nominal kilometre readings.

The Ford of Canada Ltd. cars were oil sampled at each drain, nominally 5000 km intervals.

Three oils were used: an SAE 10W20 grade for winter use, an SAE 15W30 grade for summer use and a "factory fill" SAE 30 grade. All contained the same additive chemistry which was specifically developed for methanol-fuelled spark-ignition engines by Paramins, a division of Exxon. An oil and filter change interval of 5000 km was used during the test. The eight Shell cars had an additional oil and filter change at 1000 km prior to pre-measurement.

Maintenance records on all the cars were retained to determine what problems were due to the fuel. Operational problems were obtained by placing notebooks for employee comment in all eight Shell cars.

Four of the Shell cars were tested for cold weather driveability at +5° and -10°C on a variety of fuels, as per Shell Canada's test procedure (see Appendix B). Two of the cars were tested for exhaust emissions and fuel consumption at +25°C at 1000 and 26 000 km, nominally.

Finally, problems (and eventual solutions) with the fuel dispensing system were recorded.

3/ RESULTS AND DISCUSSION

3.1/ Fuel Consumption

3.1.1/ Shell Cars

The fuel consumption of the Shell cars can be split into two groups, normal service and Aunt Minnie service, as previously defined. The fuel consumption records can also be split by fuel blend. This is necessary as the fuel blend properties were varied as per the climatic conditions expected prior to the next fill of the 1000 gal (Imp) storage tanks.

Table 4 gives results on a car-by-car basis. These results show that the four Aunt Minnie cars gave significantly inferior fuel consumption than the four normal-service cars. The consumption was typically one-third higher, but during the coldest part of the year it was one-half higher with the Aunt Minnie cars than the normal-service cars. The Aunt Minnie fuel consumption was between 1.21 and 1.51 times that of the normal-service cars.

The normal-service cars show a sinusoidal-type function of fuel consumption versus the time of year (see Figure 1). This is as expected -- fuel consumption is highest in the winter, decreasing as summer approaches and increasing again as the next winter approaches. The Aunt Minnie cars show a much larger increase from the springtime fuel consumption value to the winter value than the corresponding decrease between spring and summer fuel consumption. More data are required to confirm the effect of the cooler ambients in winter on fuel consumption in Aunt Minnie service (see Figure 2).

The effects of variations in fuel inspection properties, as given in Table 2, are hard to discern due to the large influence of ambient conditions on fuel consumption. The change in energy content of the blends was small (less than 1%), so this would have little or no effect.

The chassis dynamometer tests on the two cars, 339 and 340, yielded an average combined rating of 13.05 L/100 km. This compares to an average for the total test period of 16.1 L/100 km for car 339 and 16.0 L/100 km

for car 340, which averages to 16.1 L/100 km. The over-the-road figures for these two cars are, on average, 23% higher than the chassis dynamometer figures (see Table 5).

Typically, tests on late-model gasoline-powered cars at the Oakville Research Centre (ORC) have shown over-the-road fuel consumption values 10 to 15% higher than the chassis dynamometer tests. This difference between "real-world" consumption values and those tested by the US Environmental Protection Agency (EPA) or Transport Canada (TC) method would more than obliterate the small increase in energy efficiency evident in the chassis dynamometer tests.

The tank capacity on these cars is nominally 49.2 L. However, as no more than 46 L was installed in any of the cars (including the few times when a car ran out of fuel on the road), the latter value would be more appropriate for range calculations. The range on the cars under Aunt Minnie service would then be between 170 and 250 km. The range on the cars under normal service would be between 250 and 335 km.

The gasoline version, having a similar tank but a combined rating of 7.5 L/km, would equate to 8.42 L/100 km in average "real-world" driving, with a range of up to 550 km. This is practically double that of the methanol version.

In general, the results with this fleet indicate that methanol-fuelled cars give poorer fuel consumption than expected, especially during winter conditions.

3.1.2/ Ford Cars

Table 6 details the fuel consumption of the five Ford of Canada Ltd. cars. The fuel consumption records were not as complete with these five cars, so fewer kilometres were used during each feed blend to typify the fuel consumption.

The average results are generally between those of the Shell Aunt Minnie and normal-service vehicles. This can be seen by comparing Figure 3, a graph of the average fuel consumption of the Ford cars, versus Figures 1

and 2, which are, respectively, the Shell normal-service and Aunt Minnie service cars.

3.2/ Operational Problems

A variety of operational problems occurred with these cars. All Shell cars were equipped with a log book for the drivers to record any problems.

Table 7 shows the general type of comments and operational data received. In general, all drivers complained of poor idle quality, particularly during vehicle warm-up; stalling at idle, both immediately after starting and during vehicle warm-up; hesitation, even when fully warm; stumbling at shift changes, particularly where cold; and loud engine knock during high-speed (>100 km/h) operation.

Four no-starts were recorded over the winter, on three cars. Block heat was used 17 times, in total, on six of the cars.

Cold-start times as recorded by the vehicle drivers, combined with the actual ambient temperatures (not necessarily those recorded by the vehicle drivers, as none of the cars were equipped with ambient temperature sensors), indicate that, with 30 s of cranking, the eight cars would start at between -22 and -13°C, with no block heat, with an average of -17.5°C (see Table 7 and Figures 4 and 5). No problems with hot weather driveability (i.e., vapour lock) occurred, other than the stumble on shift and hesitation mentioned previously.

In general, the performance of the vehicles was significantly inferior to that of late-model gasoline-fuelled vehicles under similar ambient conditions.

3.3/ Maintenance Problems

A variety of problems occurred due to the use of near-neat methanol fuel in these 13 cars (Table 8 details the major problems with each of the test cars).

All the cars as initially delivered required adjustments to the distributor timing -- both static (at idle) and vacuum advance. The idle control diaphragm was disconnected as it was not intended to be operational on methanol-fuelled Escorts. Idle speed and intake manifold vacuum at idle also required adjustment. All the cars required further adjustment after a few thousand kilometres.

Because of dispensing system problems, specifically deterioration of the fuel pump dispensing hose, all the cars required removal of their fuel tanks due to plugging of the in-tank fuel filter. The majority of the Ford cars had to be towed in as a result of plugging of this in-tank fuel filter.

As the cause of this problem was not immediately determined, some of the cars had to have these filters replaced twice. Since the original hose was replaced with one compatible with the fuel blend, no further problems with these in-tank filters have occurred. However, only the cars in service with Ford still have these filters. All the Shell cars had the filters removed when the fuel tanks were removed for clean-out. One car, during the clean-out of the fuel tank, had a deteriorated fuel return line check valve. This component is intended to prevent fuel spillage after a rollover accident. This particular check valve was apparently the wrong material for "fuel methanol." No other deteriorated duckbills were noticed.

Four of the cars required replacement of the nickel-plated carburetor. One carburetor was replaced due to a part-throttle surge. The other three were replaced as they gave an insufficient amount of ported vacuum signal to the distributor, which caused increased hesitation on shifts.

All cars in normal service at Shell and all cars at Ford encountered spark plug problems due to preignition. (As previously mentioned, the ignition timing was checked and adjusted on all the cars, which alleviated this problem slightly.) Typically, one or two of the spark plugs would suffer loss of the side electrode after highway operation. This would cause poor running and loss of power. Usually cylinder four would be one of the cylinders involved. The initial plug type, AWSF12C, which

is two heat ranges colder than the gasoline Ford Escort plug, was then replaced with plug type AGSF12C.

The difference between these two plug types is in the material composition of the side electrode. They are the same heat range. After installation of these plugs in early 1984, only two cars had subsequent problems -- one at Ford and one at Shell. The side electrode can be considered as a fusible link; in general, if preignition occurs, the side electrode vaporizes, thereby shutting down that particular cylinder, prior to any other problems (i.e., valve or piston damage).

If the spark plugs suffered damage, there would usually be continuous knocking sounds (similar to knock or a ping in gasoline-fuelled engines) prior to loss of power and rough running. (Knock is defined as the noise associated with auto-ignition of a portion of the mixture ahead of the flame front advancing at normal velocity. It is a post-ignition phenomenon.) This audible knock, when continuous, appears to indicate the onset of preignition with these engines operated on "fuel methanol."

Preignition is much more damaging than knock, as it precedes the intended ignition of the fuel-air mixture in the combustion chamber by the intended ignition spark plug. This causes higher temperatures due to the longer time available for combustion, which then causes further preignition and eventually engine damage (i.e., spark plug side electrode damage).

Other researchers have found [2, 3] that with gasoline engines recalibrated for "fuel methanol" the preignition-limited spark-advance curve may be lower or the same as the knock-limited spark-advance curve in some engine operating modes. The engine may then encounter preignition either concurrent with or prior to spark knock with "fuel methanol." This may be why there have been some subsequent problems with two of the cars.

One of the Ford cars has recently encountered a stuck exhaust gas recirculation (EGR) valve, caused by deposits of unknown composition, probably related to the oil formulation. The vehicle had accumulated approximately 11 000 km. Additionally, at the same time, this car had the carburetor cleaned and rebuilt because of excessive deposits.

The deposits in the carburetor were caused by the fuel dispensing pump in use at Ford. The initial pump at Shell and the pump still in use at Ford utilize a vane-type pump with both rotor and vanes made of sintered bronze.

The use of this pump with near-neat methanol causes excessive wear of the bronze components. These components wear away, and the debris is apparently fine enough to pass through the in-tank fuel filter and the carburetor fuel filter, finally being deposited in the carburetor bowl of the vehicle. To date, no other vehicles have encountered this problem.

The catalytic converter on one of the Shell cars (No. 340) was found to be partially deactivated at 26 000 km. The deactivation may be caused by contamination of the catalyst. Other cars may have contaminated catalysts; however, only cars 339 and 340 were emission tested after distance accumulation, which uncovered this problem.

In general, there have been more maintenance problems with these cars than would be expected with gasoline. The material compatibility problems should be avoidable with further use of near-neat methanol fuel. The mechanical problems (timing adjustments and spark plug preignition damage) will require further work.

3.4/ Oil Consumption

Table 9 shows the oil change interval, type of oil used, and oil consumption for the eight cars at Shell and five cars at Ford.

The oil consumption in the normal-service cars and the five at Ford was low, typically being less than 0.5 L per oil drain of 5000 km nominal length. The use of the lower viscosity 10W20 winter grade oil had little or no effect on oil consumption.

The oil consumption of the Aunt Minnie service cars was approximately 1.5 L over 3000 km. This consumption is high due to the operational regime of the cars.

Typically, these cars had over 10% fuel dilution in the sump. At temperatures below 64°C this does not pose a problem. However, at 64°C, all the methanol components of the fuel in the sump will vaporize. When this vaporization occurs, a large amount of oil is carried up the positive crankcase ventilation (PCV) system into the air cleaner and intake manifold. Additionally, this PCV system was designed for the gasoline Escort engine with a compression ratio of 8.8:1. The methanol Escort engine has a compression ratio of 11.4:1, which will generate more blow-by.

Eventually, the design of methanol-fuelled vehicles will have to include a PCV system which avoids this problem. The present system has insufficient capacity to cope with the higher crankcase pressure and narrow boiling range characteristic of "fuel methanol."

3.5/ Used-Oil Analysis

Table 10 shows the initial inspection properties of the three oil formulations used in this program. Appendices C and D show infrared transmission graphs for new and used oils.

3.5.1/ Shell Cars

Tables 11 and 12 show the average used-oil analyses for the four Aunt Minnie and the four normal-service cars, respectively.

The Aunt Minnie car results show that the total acid number (TAN) increased by one to two numbers over the new oil, and the total base number (TBN) decreased by approximately six numbers over the test distance. This indicates that acids are being produced and neutralized in service.

The fuel dilution figure of 0.5% by volume, using the ASTM D-322 method, can be considered high, as this method will not pick up methanol contamination. This method will pick up the hydrocarbon component of the fuel, which was approximately one-tenth of the total fuel blend. Additionally, the viscosity measurements at 100°C could generally not be done because the methanol in the oil boiled and voided the test. This also indicates fuel dilution was a problem.

Pentane insolubles include oil-insoluble matter caused by contamination and oil-soluble matter caused by oil or additive degradation. In general, a high pentane insoluble level indicates that the oil can no longer hold contaminants in solution. The levels found in this program are high, indicating that there is a large amount of oil contamination and degradation. Alternatively, the additive package itself may be precipitating out, as the dosage rate is quite high (see Table 10).

Wear metals, in parts per million (ppm), are generally used to infer the condition of the engine. Appendix E shows some data from the literature, giving basic warning levels for used-oil analysis.

The aluminum levels (ppm) were higher than would be expected, due to possible corrosion by the methanol fuel in the fuel system (both on the car, i.e., the intake manifold, the cylinder head, and off the car, i.e., the dispensing nozzle) and piston wear. The chromium level is also high, indicating ring wear.

The copper level increased with distance travelled. Copper is usually associated with bearing wear. In these engines, thrust bearing wear occurs, and as the thrust surfaces are a copper alloy with no overlay, high copper levels are expected.

The iron level varied between approximately 50 and 150 ppm. The iron is a product of cylinder bore wear. The lead level was high for cars with non-leaded fuel. This was probably due to corrosion of the filler neck in the fuel tank, which is coated with terneplate, an alloy of lead and tin which is readily stripped off by "fuel methanol."

The pressure of silicon usually indicates dirt ingestion. However, comparing the silicon levels of these Aunt Minnie cars with those of the normal-service cars (see Table 12) shows that the initial high levels of silicon, 50 to 100 ppm, drop with vehicle-kilometres accumulated (or fuel usage) to 10 to 20 ppm with the normal-service cars. This level of 10 to 20 ppm would be that expected with gasoline engines in normal service, caused by dirt ingestion. The higher initial levels with these methanol-fuelled cars indicate that silicon is being removed (similar to the lead

being removed from the terneplate) from some component in the fuel dispensing system or in the car itself.

The four normal-service car average results are shown in Table 12. The TAN increased by one to one and one-half numbers, while the TBN decreased by about three numbers. Comparing this to the Aunt Minnie cars, indications are that the changes in TAN and TBN are caused by dilution by both raw and partially combusted fuel.

The fuel dilution levels are lower, and few problems were encountered with viscosity measurements at 100°C. In general, a drop approximately 0.5 cSt in viscosity occurred over the oil drain period of 5000 km. This is as expected with an oil containing no viscosity index improver. The pentane insolubles levels are acceptable, being lower than the Aunt Minnies.

The aluminum wear metal level is higher than expected and, as in the case of the Aunt Minnie cars, is primarily due to piston wear, but also possibly fuel system corrosion. The chromium levels are due to ring wear. The copper levels are high, caused by corrosion of the fuel dispensing system and bearing wear (particularly the thrust bearing in this type of engine).

The iron level of 50 ppm is similar to that expected with gasoline. The lead level, while initially high, drops with distance accumulation. This indicates that the terneplate on the fuel tank filler line is being removed. The silicon level, as explained previously, is due to both dirt ingestion and possible corrosion.

3.5.2/ Ford Cars

The results from the five cars at Ford generally reflect those of the four normal-service cars at Shell. As the distance accumulation between oil drains was generally higher, larger changes in TAN and TBN occurred (see Table 13).

Aluminum, chromium, copper, and iron were all higher than the normal-service Shell cars. Again, this is due to increased vehicle-kilometres

between oil drains. The lead and silicon levels show similar, but more pronounced, trends to the Shell cars.

All other used-oil results were similar to those discussed previously.

3.5.3/ Other Cars

Average results for four other cars are given in Table 14. Again, there are no real differences between these and both the Ford and Shell cars.

Wear metals for the average Aunt Minnie, normal-service and Ford cars are presented graphically in Figures 6, 7 and 8.

3.6/ Engine Ratings

All eight cars at Shell were dismantled after test completion and rated for sludge and varnish deposits, clogging, sticking intake valve deposits and valve deposit weights.

Tables 15 and 16 detail the results. In general, the level of sludge present is very low, and there is no difference between the Aunt Minnie and the normal-service groups. The average rating was 9.79 (where 10 is clean). This is probably due to the low level of heavy hydrocarbons and other organic compounds (i.e., sulfur based) in the test fuel.

The varnish ratings, giving 9.27 and 9.10 average, for the Aunt Minnie and normal-service groups are also very good. Varnish formation is time and temperature related, so the higher level for the normal-service cars is expected.

No clogged or stuck components were found in any of the eight cars.

The intake valve deposits were also rated. The normal-service average result of 9.0 is excellent. Gasoline-powered cars would give ratings of 6 to 8, where 10 is clean, after similar distance accumulation. The poorer rating of 8.8 in Aunt Minnie service indicates that low temperature operation promotes valve deposits with "fuel methanol."

The intake valve deposit weights are also low, about 0.2 g to 0.4 g, compared to gasoline cars, where 1 to 3 g would be more typical. This is due to the low oil consumption of the cars and the lack of a carburetor cleanliness additive in the methanol fuel.

It should be noted that the majority of the deposits in the valves were on the face and were extremely hard. These deposits may be related to the oil, which was high in calcium-based detergent and concomitant ash level (see Table 10).

The exhaust valve deposits were also weighed. Again, the majority of the deposits were on the valve face and were extremely hard. The normal-service cars had two or three times the amount of deposit compared to the Aunt Minnie cars. These levels are higher than expected with the fuel and is most likely due to the high ash oil. Additionally, these deposits may be responsible for the preignition problems with these cars.

3.7/ Engine Wear Results

The Table 17 details the dimensional changes in the components measured in four of the Shell cars (two in each service).

The Aunt Minnie cars gave relatively low wear results. The ring and bore wear were acceptable. The only area of concern is the rather high loss in camshaft lobe height.

Additionally, some rusting of crankshaft journals, camshaft lobes, lifters and cylinder bores was evident.

The two normal-service cars gave relatively good results as well. The level of ring wear as indicated by ring gap growth and ring side clearance was higher than would be expected with gasoline at a similar level of use. Some rusting of crankshaft journals, camshaft lobes, lifters and cylinder bores was also evident.

Car No. 340 had some scores on both the thrust and anti-thrust sides of the piston and bore hole No. 1 cylinder. The damage extent was moderate.

The weight losses are given in Table 18. The main bearing weight losses are high in both services, and the rod bearing weight losses in normal service are also high. However, the other weight losses given are considered acceptable. Some of the rocker arms and pivots showed an increase in weight. This was probably due to the absorption of either oil or fuel by these components during service.

3.8/ Engine Durability

In general, the results with this oil additive package in these types of services were quite good.

In Aunt Minnie service the oil performed well. However, the test was not considered severe enough. The Sequence IID or Aunt Minnie field test uses gasoline with a high lead content to increase the rusting severity of the test. No similar additive approach could be taken with these methanol-fuelled cars.

The used-oil analysis results for these cars indicate that more distance accumulation would be required for a sufficiently severe test.

The problems with emulsion formation and excessive boiling of the oil-fuel mixture at temperatures in excess of 64°C are an impediment to the use of methanol-fuelled internal combustion engines in cold climates.

The normal-service car results show that there is higher ring and bearing wear than with gasoline. There are also excessive valve face deposits, which are probably due to the oil and may be related to the preignition problems.

The varnish and sludge levels with methanol as a fuel are good, as are the deposits in the stem and tulip areas of the intake valves.

The short oil drain interval of 5000 km versus, typically, 12 000 km with gasoline-powered engines and the lack of multi-grade capability in the oil (which increased the winter starting problems) are also severe impediments to the use of methanol in engines in cold climates.

Combining the used-oil analyses with the engine wear ratings indicates that methanol engines would be expected to have shorter life spans than those powered by gasoline in colder climates, which again is a severe impediment to the use of methanol in internal combustion engines in Canada.

3.9/ Other Technical Evaluations

3.9.1/ Cold Weather Driveability

Four of the eight 1983 Ford Escorts in service at Shell were driveability tested at +5 and -10°C. The oil in these cars at that time was the SAE 10W20 grade.

Five fuels were blended for testing based, in part, upon the results with Phase 1 of the program. Table 19 lists the fuels and their inspection properties. The fuels contained three components: methanol (MeOH), super non-leaded winter grade gasoline (SNL-W) and dimethyl ether (DME), whose properties are given in Table 20.

The Oakville Research Centre (ORC) driveability procedure was used, with modifications, for all testing (see Appendix B). This procedure quantifies the hesitation, stumble, backfire and stalling characteristics of a vehicle under both part- and full-throttle operation during warm-up. Demerits are assigned by the driver-rater, based on a subjective assessment of the type and severity of the malfunction [1].

The modifications to the normal ORC driveability procedure were to exclude the cold startability of the vehicle from the evaluation and include a 30 s idle subsequent to the start, prior to the initial driveaway.

The results obtained on all five at a nominal test temperature of +5°C and on four of the fuels at a nominal test temperature of -10°C are given in Table 21. Table 22 lists the linear regressions of driveability demerit onto temperature for each individual fuel (excluding pure methanol) and also onto both temperature and percent DME for all the fuels.

The latent heat of evaporation at 0°C was calculated for each of the five blends (as given in Table 19) as it was felt that this may correlate with the driveability performance of the vehicles. However, statistical analysis indicates that dry Reid vapour pressure (RVP) is linearly related to the calculated latent heat of evaporation at 0°C. Additionally, the percent by mass DME added to the blends correlates with the dry RVP of the blends.

This indicates that driveability demerits can be related to the latent heat of evaporation, the DME content or the dry RVP of these blends, combined with ambient temperature.

This relationship may not hold for other priming agents used in near-neat methanol (i.e., butane, isopentane, etc.) as all the blends tested in this program were similar (basically a blend of methanol and SNL-W with increasing amounts of DME added).

The cold weather driveability tests reported in Phase 1 used a slight variation of the ORC driveability procedure. Because of unseasonably warm temperatures, the cars were cold-soaked at the required test temperatures and then tested outside at the current ambient temperature, if it was within 10°C of the required test temperature [1]. This means that the ambient temperature was generally 5 to 10°C warmer than the initial engine or test temperature.

The results from these prior tests were significantly better than the present results. The average of the six fuels tested was 39 demerits at +5°C and 57 demerits at -10°C, indicating that ambient temperature has a major influence on driveability performance, more so than engine temperature.

Table 23 shows typical driveability demerit levels on commercially available winter gasolines with a 1982 Ford Escort [1].

Comparing these results shows that even on Blend E, the most volatile blend, the methanol version gives one and one-half times the demerit level at +5°C and three and one-half times the demerit level at -10°C, compared to the gasoline version.

In general, this performance would not be considered acceptable to the average consumer.

3.9.2/ Exhaust Emissions

The exhaust emissions, as per Transport Canada methods, were measured on two of the Shell cars at +25°C, in duplicate. Tests were performed at nominal odometer readings of 1000 and 20 000 km for car 339 and 1000 and 26 000 km for car 340 (Appendix F).

The fuel used was a blend of 90% by volume methanol and 10% by volume super non-leaded gasoline (winter grade), spiked with 5% by mass dimethyl ether.

Results are given in Table 24. The results for car 340 at 26 000 km dropped after the catalytic converter was changed, indicating that the converter was contaminated with some unknown compound or possibly overheated. This contamination is considered atypical. The converter has been given to Ford Motor Company Ltd. for analysis.

The effect of kilometre accumulation is evident. The emissions of both HC and CO have approximately doubled over the accumulation of an average of 22 000 km. Ford representatives indicated that car 340 may have also had an air pump or thermostat problem, which would cause higher CO emissions. NO_X emissions have remained relatively constant. In prior testing at ORC, gasoline cars have yielded typical increases of 50% on HC and CO and 10% on NO_X over the same 22 000 km average.

The cars were calibrated to meet 1983 California standards. The NO_X results passed at both test increments. The CO results passed at 1000 km, though after kilometre accumulation the CO results exceeded the standard by approximately 25%. The HC result exceeded the standard both initially, by approximately 13% and at the test, by approximately 150%. However, both cars still met 1983 Canadian standards at both test increments.

Some general conclusions can be inferred from these results, although it should be noted that as only a limited number of tests have been per-

formed on two vehicles, these conclusions should be regarded as tentative. The indications are that these first-generation methanol-fuelled Ford Escorts have poorer emission hardware durability than their gasoline counterparts when operated in a cold climate. This may be due to oil formulation, the fuel configuration or the vehicle hardware.

3.9.3/ Fuel Consumption

The fuel consumptions, as per Transport Canada methods and at 60 and 100 km/h, were measured on the chassis dynamometer. The tests were performed in conjunction with exhaust emission testing on two of the Shell cars, 339 and 340. Car 339 was tested at 1000 and 21 000 km. Car 340 was tested at 1000 and 26 000 km.

Table 5 details the fuel consumption values obtained with these two cars. The fuel used was a blend of 86.3% by mass methanol, 8.9% by mass super non-leaded winter grade gasoline and 4.8% by mass dimethyl ether.

The combined ratings of 13.09 L/100 km at 1000 km and 13.01 L/100 km at 23 000 km can be compared to a combined rating for a 1983 gasoline Ford Escort (as tested by Transport Canada) of 7.5 L/100 km. The energy content of the methanol test fuel would be about 17.6 MJ/L, whereas gasoline would be approximately 32.2 MJ/L. This means the methanol vehicle consumed approximately 230 MJ/100 km, and the equivalent gasoline vehicle would consume approximately 242 MJ/100 km. This equates to an efficiency increase of approximately 5% for the methanol version, when tested under the Transport Canada method at +25°C.

Generally, with gasoline-fuelled cars, fuel consumption decreases as kilometres accumulate (for 23 000 km, a decrease of approximately 5% in the combined rating would be expected). These two particular methanol-powered cars showed no drop in fuel consumption.

3.9.4/ Fuel Dispensing System

A variety of problems occurred with, or due to, the configuration of the fuel dispensing system. The problems are listed in the following in chronological order.

In June 1983, two 1000 gal (Imp) steel tanks equipped with a Fillrite pump (Model NP-701) were installed by an outside contractor, Serv-A-Station of Dundas, Ontario, at both Shell and Ford locations in Oakville, Ontario. An in-line Wix fuel filter, a Goodyear 3/4 in. (1.9 cm) Flexsteel (#299-1) fuel hose and an automatic shutoff nozzle (OPW-1A) were the major components of the fuel dispensing system.

Later the same month, the Wix filters on both pumps were removed due to corrosion of both the filter and aluminum filter head. A representative from Canadian Fram Limited inspected both installations and supplied a Fram PG-3334 in-line filter and a cast-iron filter head which proved to be compatible with the methanol fuel blends. These filters are changed every four months and show no evidence of metallic corrosion.

Also in June, within one week of service, the fuel in the dispensing hose would turn yellow in colour with small fibres suspended throughout the liquid. A Gates 125 HW nitrile-lined fuel line hose was installed, but in two days the methanol blend also turned a flocculent yellow. This flocculent plugged the in-tank fuel filters of a number of the cars in operation at Shell and at Ford.

A variety of hose manufacturers were then contacted regarding the compatibility of the methanol blend which contained both highly aromatic non-leaded gasoline and polar methanol. The discussions resulted in a recommendation to use a teflon-lined stainless steel braided hose covered with a nitrile rubber casing, obtained from T&T Liquid Handling of Hamilton, Ontario. Once installed, no further fuel contamination problems were encountered. However, the hose started to kink in various places, causing restrictions in flow.

To alleviate this new problem, the Dayco Rubber Company was contacted, and they provided a sample of their Dayco #7192 hose lined with textile cord. As expected, a sample of the methanol blend became contaminated with flocculent after a few days.

After the Dayco Rubber Company was informed of these problems, they sent a sample of their #7276 hose. This is a poly-chem hose with a hypolon casing and cross-linked polyethylene lining. No methanol blend contamin-

ation occurred after a lengthy soak trial. This hose is presently being used in both dispensing systems.

The automatic shutoff nozzles (OPW-1A) were inspected after one month's use. The automatic plunger release seal became swollen upon removal, but there was no indication of metallic corrosion. Occasionally these nozzles have failed (i.e., not shutting off automatically, again, because swelling of the plunger release seal causes the valve to stick open).

A variety of problems with the Model NP-701 pump (manufactured by Fillrite of Fort Wayne, Indiana) were encountered throughout this program. The teflon-coated meter (Series 800A) gave no problems, but various internal components of the pump constantly caused pump failure.

The pump is a five slider vane-type pump. The housing is made of cast iron, and both the vanes and rotor are made of sintered bronze. The pump is close-coupled to an electric motor. The check (or foot) valve is located just below the pump and not at the bottom of the storage tank.

The first problem encountered was swelling of the main shaft seal of the pump, causing the rotor to press against the shaft end plate, thereby stopping pump rotation. This swelling occurred after a few weeks service using the 90% by volume methanol and 10% by volume super non-leaded gasoline blend. Dimethyl ether (DME) was added to the fuel blend during the winter months to aid cold startability, but this addition and, possibly, the lower ambient temperatures promoted this seal swelling problem, causing pump seizure in as little as two days.

Petroquip Limited, the local distributor of Fillrite Pumps, became involved and machined the pump rotor to provide more end-plate clearance to accommodate the swollen seal. This did not provide any increase in service life.

The seals in the pump which became swollen were made of Buna-N type rubber. Petroquip contacted Precision Seal in Orillia, Ontario, who provided two compounds for testing, namely, EDPM (ethylene propylene), and Aflas (a tetrafluoroethylene [TFE] propylene developed by Asahi Glass). The two compounds were weighed and measured and then soaked in the winter

methanol blend for one week. The Aflas gave no swelling or weight increase after this time period. The EDPM increased in both size and weight. Pump shaft seals of Aflas were then specially manufactured for the Fillrite pump.

After installation of the Aflas shaft seal, the pump seized again after three days. The pump was dismantled and no seals were found to be swollen. However, the vanes were excessively worn and were binding in the ports of the cast-iron housing.

To avoid further wear problems, Durable Release Coaters of Bramalea, Ontario, were contacted regarding suitable anti-wear coatings. Ten new vanes were coated with a light fluorocarbon coating containing polytetrafluoroethylene (PTFE), #DR5500, and 10 other new vanes were coated with a dark fluorocarbon coating also containing PTFE, #DR5150. The light coating contains more PTFE than the dark coating, giving a lower coefficient of friction.

The dark-coated vanes (#DR5150) only lasted three days before pump seizure. The light-coated vanes (#DR5500) have been operating in one pump for over three months with no pump seizures due to excessive wear. These coatings are used on some carburetor throttle shafts.

Additionally, the seal on the check (or foot) valve on the suction side of the pump caused pump failure. After approximately one week of operation on either the winter or summer methanol blends, these valve assemblies would leak due to seal swelling. The pump would then lose prime and run dry, causing both vane wear and pump failure. Eventually the pump would regain its prime, but would lose it again after the motor was shut off.

The deposits in the carburetor were caused by the fuel dispensing pump in use at Ford. The initial pump at Shell and the pump still in use at Ford utilized a vane-type pump with both rotor and vanes made of sintered bronze.

The use of this pump with near-neat methanol causes excessive wear of the bronze components. These components wear away, and the debris is appar-

ently fine enough to pass through the in-tank fuel filter and the carburetor fuel filter before being deposited in the carburetor bowl of the vehicle. To date, no other vehicles have had this problem.

Finally, the catalytic convertor on one of the Shell cars (No. 340) was found to be partially deactivated at 26 000 km. The deactivation may have been caused by contamination of the catalyst. Other cars may have contaminated catalysts; however, only cars 339 and 340 were emission-tested after vehicle-kilometre accumulation, which uncovered this problem.

In general, there have been more maintenance problems with these cars than would be expected with gasoline. The material compatibility problems should be avoidable with further use of near-neat methanol fuel.

The mechanical problems (timing adjustments and spark plug preignition damage) will require further work.

Additional problems will be monitored in Phases 3 and 4 of the Ford/Shell program, sponsored by the participants, the Ontario Ministries of Energy and Transportation and Communications and the federal government of Canada.

4/ CONCLUSIONS

1/ Fuel consumption was poor with these cars, particularly at lower ambient temperatures and under stop-and-start conditions.

2/ Operational problems due to the use of near-neat methanol fuel in a cold climate were evident. In general, the cold startability and driveability of these vehicles at low temperatures would be unacceptable to consumers.

3/ Maintenance problems caused by the use of near-neat methanol fuel were evident. The majority of these problems were due to material incompatibility with the fuel blend.

4/ Oil consumption was low with these engines.

5/ Used-oil analysis and engine-wear results indicate that methanol-fuelled engines would have shorter life spans than gasoline-fuelled engines, when operated in a cold climate.

6/ The exhaust emission of these cars are acceptable, though there is some question over the durability of emission hardware in comparison with gasoline-powered cars, when operated in a cold climate.

7/ The over-the-road fuel consumption is typically 23% higher than that measured on the chassis dynamometer, compared to a value of 10 to 15% for gasoline-powered cars.

8/ Problems with fuel dispensing systems should be expected with methanol-gasoline blends.

5/ RECOMMENDATIONS

For near-neat methanol (or "fuel methanol") to be a viable fuel for internal combustion engines in a cold climate such as that occurring in Canada, the following issues must be addressed:

1/ improvements in cold weather performance (including startability, driveability and fuel consumption) via both hardware- and fuel-related developments;

2/ improvements in engine durability (including engine maintenance, engine oil formulation, and emission equipment);

3/ improvements in the fuel dispensing system to ensure compatibility with near-neat methanol fuel;

4/ further improvements in the energy efficiency versus other competitive fuels (i.e., gasoline).

6/ REFERENCES

[1] Mitchell, D.K., "Straight Methanol and Vehicle Evaluation - Phase 1, The Cold Weather Performance of a Variety of Methanol Fuel Blends," AF-84-03, Transportation Energy Management Program, April 1984, Downsview, Ontario, Canada.

[2] Menrad, H., Haselhorst, M., and Erwig, W., "Pre-Ignition and Knock Behaviour of Alcohol Fuels," Paper 821210, Society of Automotive Engineers, 1982, Warrendale, Pa., USA.

[3] Menrad, H., Decker, G., and Weidmann, K., "Alcohol Fuel Vehicles of Volkswagen," Paper 820968, Society of Automotive Engineers, 1982, Warrendale, Pa., USA.

Table 1/ Test Vehicle Specifications

Model:	1983 Ford Escort
Body Styles:	4-door hatchback - station wagon
Engine Type:	OHC, in-line 4-cylinder
Bore x Stroke:	80 x 79 mm
Capacity:	1.6 L
Compression Ratio:	11.8:1
Power Output:	85 hp @ 5200 rpm
Top Ring Type:	barrel-faced, chrome-plated
Head Gasket:	1984 Type - stainless steel fire rings
Camshaft Type:	base
Distributor:	modified spark curve (vs. gasoline version)
Spark Plug Type:	AWSF 12C then AGSF12C
Fuel System Specification:	- stainless steel fuel tank - stainless steel fuel lines - nickel-plated in-tank sending unit - nylon-coated fuel tank straps - nickel-plated fuel pump - nickel-plated, recalibrated, carburetor - new carburetor spacer with electrical heating unit

Table 2/ Test Fuel Blend Properties

		BLEND 1		BLEND 2	
COMPONENTS		% by vol.	% by mass	% by vol.	% by mass
Methanol (MeOH)		90.0	90.6	84.8	86.2
Super Non-leaded Gasoline (SNL)		10.0	9.4	9.4	8.9
DiMethyl Ether (DME)		0.0	0.0	5.8	4.9
% by mass DME added			0.0		5.2
TIME PERIOD		July 7/83 to Nov. 29/83		Nov. 29/83 to Jan. 24/84	
INSPECTION PROPERTIES					
Density, kg/L		0.791		0.787	
ASTM D-86 DISTILLATION	IBP, °C	48		35	
	10% evap., °C	62		56	
	50% evap., °C	64		64	
	90% evap., °C	64		64	
	EP, °C	66		66	
	% Recovery	99.2		95.5	
C, % by mass			43.1		42.0
H, % by mass			12.6		12.5
O, % by mass			44.3		45.5
RVP (dry), kPa (psi)		51.0	(7.4)	96.0	(13.9)
Energy Content MJ/kg (calculated) (net or LH values)		17.5	22.1	17.6	22.4
	MJ/L				
Energy Content Blend 1 (MJ/L) / Energy Content Blend N (MJ/L)		1.000		0.994	

BLEND 3		BLEND 4		BLEND 5		BLENDS 6 AND 7	
% by vol.	% by mass	% by vol.	% by mass	% by vol.	by mass	% by vol.	% by mass
84.0	85.5	84.9	86.3	89.5	90.3	90.0	90.6
9.3	8.8	9.4	8.9	10.5	9.3	10.0	9.4
6.7	5.7	5.7	4.8	0.5	0.4	0.0	0.0
	6.0		5.0		0.0		0.0
Jan. 24/84 to April 3/84		April 3/84 to May 16/84		May 16/84 to July 17/84		July 17/84 to Nov. 17/84	
0.784		0.785		0.792		0.793	
26		36		45		52	
61		57		62		62	
64		64		64		64	
-		64		64		64	
-		67		66		67	
>90[1]		95.5		98.4		97.6	
	42.7		42.1		41.6		41.9
	12.6		12.6		12.5		12.7
	44.7		45.3		45.9		45.4
100.0	(14.5)	92.0	(13.3)	66.0	(9.6)	49.2	(7.1)
	22.5		22.4		22.1		22.1
17.6		17.6		17.5		17.5	
0.994		0.994		1.000		1.000	

[1] - Test terminated early due to loss of meniscus movement at greater than 90% recovery

Table 3/ Base Component Properties

Inspection Properties		SNL-W (Prior to July 17/84)	SNL-W (After July 17/84)	DME	MeOH
Density, kg/L		0.740	0.750	0.661	0.797
ASTM D-86	IBP, °C	32	29	-25	64
Distillation	10% evap., °C	42	47	-	64
	50% evap., °C	97	101	-	64
	90% evap., °C	155	156	-	64
	EP, °C	198	198	-25	67
	% recovery	97.1	98.4	-	99.8
C, % by mass		86.77	86.65	52.1	37.5
H, % by mass		13.13	13.35	13.0	12.5
O, % by mass		0.00	0.00	34.9	50.0
RVP (dry), kPa (psi)		86 (12.5)	68 (9.9)	850 (123)	32 (4.6)
Energy Content	MJ/kg	43.5	43.5	28.9	19.9
(Book Values)	MJ/L	32.2	32.2	19.1	15.9
(net or LH values)					

Table 4/ Fuel Consumption -- Shell Cars

BLEND NO.	DATE	CAR NO.	333	334	335	336	Ave.	337	338	339	340	Ave.
1	July 7/83	L/100 km	15.9	16.0	16.8	18.2	16.7	17.3	13.2	16.3	16.0	15.7
	to	MPIG	17.8	17.7	16.8	15.5	17.0	16.4	21.4	17.3	17.7	18.0
	Nov. 28/83	L	160	158	123	233		293	202	421	362	
		km	1006	1037	730	1283		1696	772	2579	2263	
2	Nov. 28/83	L/100 km	30.3	23.5	29.0	27.6	27.3	16.9	18.5	18.5	18.4	18.1
	to	MPIG	9.3	12.0	9.7	10.2	10.3	16.7	15.3	15.3	15.4	15.6
	Jan. 23/84	L	122	132	119	138		551	629	642	747	
		km	403	562	410	500		3256	3399	3468	4055	
3	Jan. 23/84	L/100 km	20.2	19.6	20.0	22.7	20.7	16.7	15.9	17.5	18.2	17.1
	to	MPIG	14.0	14.4	14.1	12.4	13.7	16.9	17.8	16.2	15.5	16.5
	April 2/84	L	169	133	151	174		380	967	772	923	
		km	835	680	754	767		2271	6087	4414	5065	
4	April 2/84	L/100 km	20.2	19.2	20.5	17.6	19.3	15.3	14.4	15.3	15.4	15.1
	to	MPIG	14.0	14.7	13.8	16.1	14.6	18.5	19.6	18.4	18.3	18.7
	May 16/84	L	104	119	94	123		396	578	627	574	
		km	516	620	444	700		2595	4006	4090	3717	
5	May 16/84	L/100 km	19.0	18.1	18.5		18.5	12.5	14.4	14.7	13.7	13.8
	to	MPIG	14.9	15.6	15.3		15.3	22.5	19.7	19.2	20.6	20.4
	July 16/84	L	40	58	121			594	702	720	713	
		km	211	320	654			4738	4885	4899	5205	
6	July 16/84	L/100 km						15.1	14.6	15.3	14.5	14.9
	to	MPIG						18.7	19.3	18.5	19.5	19.0
	Nov. 1/84	L						1549	772	774	592	
		km						10250	5272	5059	4085	
-	Overall	L/100 km	20.0	18.6	20.3	20.6	19.9	15.2	15.4	16.1	16.0	15.7
	Results	MPIG	14.1	15.2	13.9	13.7	14.2	18.6	18.4	17.5	17.7	18.0
		L	595	600	608	668		3763	3750	3956	3911	
		km	2971	3219	2992	3250		24806	24421	24509	24390	

Table 5/ Fuel Consumption Results

Nominal km	Blend Type	Car No.	Test Temp °C	Fuel Economy L/100 km					
				Urban Rating	Highway Rating	Combined Rating	Steady State 60 km/h	Steady State 100 km/h	
1 000	90/10 + 5 DME	339	+25	14.93	10.49	12.93	7.26	11.42	
1 000	90/10 + 5 DME	340	+25	15.69	10.26	13.25	7.89	11.29	
1 000	90/10 + 5 DME	Avg.	+25	15.31	10.38	13.09	7.58	11.36	Row 1
21 000	90/10 + 5 DME	339	+25	16.01	10.73	13.64	8.34	10.99	
			+25	15.84	10.85	13.59	8.42	11.23	
		Avg.*		15.93	10.79	13.62	8.38	11.11	
26 000	90/10 + 5 DME	340	+25	14.71	9.78	12.49	7.55	10.63	
			+25	14.59	9.86	12.46	7.62	10.37	
			+25**	14.34	9.69	12.25	-	-	
		Avg.†		14.55	9.78	12.40	7.59	10.50	
23 000	90/10 + 5 DME	Avg.●	+25	15.24	10.29	13.01	7.99	10.81	Row 2
$\frac{\text{Row 1 - Row 2}}{\text{Row 2}} \times 100$, %				+0.5●●	+0.9	+0.6	-5.1	+5.1	

* Average of two runs on 339

** Test repeated with a new catalyst

† Average of all three runs in 340

● Average of the two averages above (Ref. Footnotes 1 and 3)

●● A positive value indicates that the fuel consumption has dropped, a negative value indicates the fuel consumption has increased

Table 6/ Fuel Consumption -- Ford Cars

BLEND NO.	DATE	CAR NO.	342 R. Bright	343 B. Bly	344 C. Phillips	345 T. Dobson	350 B. Shadlock	Average
1	July 7/83	L/100 km	17.6	15.8	16.6	15.0	20.4	17.1
	to	MPIG	16.1	17.9	17.0	18.8	13.8	16.5
	Nov. 28/83	L	1190	1607.5	938	785	398.5	-
		km	6746	10167	5661	5220	1956	-
2	Nov. 28/83	L/100 km	18.7	18.3	19.1	16.5	21.8	18.7
	to	MPIG	15.1	15.4	14.8	17.1	13.0	15.1
	Jan. 23/84	L	373	182	176	175	224.5	-
		km	1726	997	924	1058	1028	-
3	Jan. 23/84	L/100 km	19.5	18.6	17.1	18.9	21.8	19.2
	to	MPIG	14.5	15.2	16.5	14.9	13.0	14.7
	April 2/84	L	464	511	588	269	301	-
		km	2382	2755	3440	1424	1381	-
4	April 2/84	L/100 km	18.1	16.6	16.1	15.3	19.8	17.2
	to	MPIG	15.6	17.0	17.5	18.5	14.3	16.4
	May 16/84	L	390	472	311	288	201	-
		km	2153	2847	1934	1488	1013	-
5	May 16/84	L/100 km	20.8	18.3	16.3	16.2	18.6	18.0
	to	MPIG	13.6	15.4	17.3	17.4	15.2	15.7
	July 16/84	L	483	105	70	116	182	-
		km	2343	573	430	716	978	-
6	July 16/84	L/100 km	16.9	15.2	15.9	14.3	18.4	16.1
	to	MPIG	16.7	18.6	17.8	19.8	15.4	17.5
	Nov. 31/84	L	1379	1360	1208	614	517	-
		km	8161	8940	7585	4301	2804	-
-	Overall	L/100 km	18.0	16.1	16.5	15.8	19.9	17.3
	Results	MPIG	15.7	17.5	17.1	17.9	14.2	16.3
		L	4233	4237.5	3291	2247	1824	-
		km	23511	26279	19974	14207	9160	-

Table 7/ Operational Problems -- Shell Cars

Car No.	333	334	335	336	337	338	339	340	Ave.
Poor idle quality	✓	✓	✓	✓	✓	✓	✓	✓	✓
Stalling after initial start	✓	✓	✓	✓	✓	✓	✓	✓	✓
Stalling at idle during vehicle warm-up	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hesitation	✓	✓	✓	✓	✓	✓	✓	✓	✓
Stumble at shift changes	✓	✓	✓	✓	✓	✓	✓	✓	✓
Engine Knock					✓	✓	✓	✓	✓
Time to start/ambient temperature, s /°C after a 16 h soak	2/4 7/-5 8/0 1/3 10/-6 11/-15 8/-12 11/-16 15/-16 7/-6	2/6 7/0 12/-3 5/-5 4/-3 24/-12 20/-16 12/-13 10/-11 20/-14	2/-3 6/-9 3/-8 25/-15 25/-15 2/4 4/-1 4/-4	2/2 6/5 4/-3 6/-3 5/-2 30/-16 15/-15 25/-14 15/-12 25/-17	16/-14 15/-14 5/-6 4/-3 8/-13 8/-9	25/-10 24/-14 13/-5 6/0 30/-15	2/0 5/-5 25/-15 12/-10 15/-15 25/-20 3/3 1/6	6/-5 15/-15 12/-14 17/-21 15/-20 14/-15 18/-20 12/-16 1/8	
Temp. to start with 30 s cranking, °C after a 16 h soak	→	→	-16 ←	←	→	→	-19 ←	←	-17.5
Block heat used	///		//////	///	//	/		//	//
No starts			✓		///			✓	✓

Table 8/ Maintenance Problems -- All Cars

		Shell Cars								Ford Cars							
Problem	Car No.	333	334	335	336	337	338	339	340	329	330	331	342	343	344	345	350
Distributor timing/idle speed/idle vacuum		✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓	✓	✓	✓	✓	✓	✓	✓
In tank fuel filter and tank cleanout		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓✓	✓	✓	✓	✓
Duckbill deterioration				✓													
Carburetor replacement				✓							✓				✓		✓
Plug preignition with AWSF12C				✓		✓✓	✓	✓✓	✓	✓	✓	✓	✓✓✓	✓✓✓	✓	✓	✓
Plug preignition with AGSF12C							✓							✓			
Stuck EGR valve																	✓
Carburetor Deposits																	✓

Table 9/ Oil Change Data -- All Cars

OIL CHANGE	CAR. NO. / DETAILS	SHELL CARS								FORD CARS				
		333	334	335	336	337	338	339	340	342	343	344	345	350
1	- Odometer Reading	1147	1058	1005	1007	1123	1082	986	1013	4847	5755	8706	6960	5426
	- km on oil	1147	1058	1005	1007	1123	1082	986	1013	4847	5755	8706	6960	5426
	- Oil type	F.P.P.	F.P.P.	F.P.P.	F.P.P.	F.P.P.	F.P.P.	F.P.P.	F.P.P.	F.P.P.	F.P.P.	F.P.P.	F.P.P.	F.P.P.
	- Oil grade	30	30	30	30	30	30	30	30	30	30	30	30	30
	- Oil consumption, L	0	0	0	0	0	0	0	0	0	2.0	1.0	2.0	0
2	- Odometer Reading	4006	4000	3991	4015	6060	5982	6695	6066	11656	12107	14262	15702+	10264
	- km on oil	2859	2942	2986	3008	4937	4900	5712	5053	6809	6352	5556	6742+	4838
	- Oil type	W.G.	W.G.	W.G.	W.G.	W.G.	W.G.	W.G.	W.G.	F.P.P.	F.P.P.	W.G.	W.G.	W.G.
	- Oil grade	10W20	10W20	10W20	10W20	10W20	10W20	10W20	10W20	30	30	10W20	10W20	10W20
	- Oil consumption, L	1.3	1.2	1.5	1.8	0	0.4	0	0	0	0	0	1.0	0
3	- Odometer Reading					10938	11042	11237	11081	17339	16220	27291		
	- km on oil					4878	5060	4542	5015	5683	4113	13029		
	- Oil type					W.G.	W.G.	W.G.	W.G.	W.G.	W.G.	F.P.P.		
	- Oil grade					10W20	10W20	10W20	10W20	10W20	10W20	30		
	- Oil consumption, L					0.8	0.4	0	0.4	1.0	0	1.0		
4	- Odometer Reading					16000	16438	16343	16071	24885	22437			
	- km on oil					5062	5396	5106	4990	7546	6217			
	- Oil type					S.G.	W.G.	W.G.	W.G.	W.G.	W.G.			
	- Oil grade					15W30	10W20	10W20	10W20	10W20	10W20			
	- Oil consumption, L					0	0.4	0.2	0.4	1.0	0			
5	- Odometer Reading					20991	20996	21028	21657	31082	30857			
	- km on oil					4991	4558	4685	5586	6197	8420			
	- Oil type					S.G.	S.G.	S.G.	S.G.	S.G.	S.G.			
	- Oil grade					15W30	15W30	15W30	15W30	15W30	15W30			
	- Oil consumption, L					0	0.5	0.4	0.6	0	1.0			
6	- Odometer Reading					26130	26125	26000	26897					
	- km on oil					5139	5129	4972	5240					
	- Oil type					S.G.	S.G.	S.G.	S.G.					
	- Oil grade					15W30	15W30	15W30	15W30					
	- Oil consumption, L					0	1.0	0	0					

F.P.P. - Ford Factory Fill Oil, SAE 30
W.G. - Winter Grade Oil, SAE 10W20
S.G. - Summer Grade Oil, SAE 15W30

Table 10/ Lubricant Specifications

	OIL TYPE		
COMPONENTS	FORD FAC. FILL	SHELL 10W20	SHELL 15W30
Base Oil	✓	✓	✓
Synthetic Oil		✓	✓
Additive Package	✓	✓	✓
PROPERTIES			
Viscosity @ 40°C, cSt	81.4	52.4	77.6
Viscosity @100°C, cSt	10.2	8.3	10.8
CCS Viscosity @-15°C, cP	-	-	3325
@-20°C, cP	-	2750	-
Pour Point, °C	-36	-42	-42
Density, kg/L	0.898	0.890	0.893
Sulphated ash, % by mass	2.81	2.88	2.89
Phosphorus, % by mass	0.15	0.16	0.16
Magnesium, mg/kg	28	24	24
Zinc, % by mass	0.18	0.19	0.19
Calcium, % by mass	0.73	0.77	0.76
TANe, D-664 mgKOH/g	2.3	2.4	2.3
TBNe, D-664 mgKOH/g	12.6	12.4	12.8
TBNe, D-2896 mgKOH/g	16.7	16.6	16.8

Table 11/ Methanol Fleet Used-Oil Analysis -- Shell Cars

333, 334, 335, 336 AVERAGE (AUNT MINNIE SERVICE)

OIL GRADE	FORD FAC. FILL 30	10W20	10W20	10W20	10W20	10W20	10W20
km	1054	1493	2096	2614	3018	3507	4003
TANe mgKOH/g D-664	4.26	-	3.1	2.91	2.58	2.76	3.02
TBNe mgKOH/g D-2896	17.8	-	17.5	-	14.1	12.8[2]	11.7
Fuel Dilution D-322	0.45	-	-	-	-	-	0.5[1]
Visc. @100°C	9.79 44.5@40°C	44.7 @40°C	47.0 @40°C	-	-	7.72[1]	FD
Pentane Insols. D-893	<0.28	0.98	0.88	1.47	1.73	1.14	0.85
Al	8.3	5.2	7.9	9.2	12.4	11.2	14.9
Cr	1.7	1.4	4.0	3.2	7.2	2.7	5.8
Cu	17.9	9.8	25.9	53.4	58.0	78.9	139.9
Fe	31.7	25.6	65.6	95.4	93.2	114.8	146.3
Pb	180	58.6	114.3	130.5	143	148.5	624
Si	80.8	45.3	59.2	34.8	59.61	41.7	38.9
Pour Point °C	-37	-	-	-	-	-	-48[2]
Flash Point °C	215	-	-	-	-	-	225[2]
Oil Consumption							1.5
Notes				2 Car Avg.	3 Car Avg.	[1] 3 Car Avg.	Drain
						[2] 2 car Avg.	

Table 12/ Methanol Fleet Used-Oil Analysis -- Shell Cars

342, 343, 344, 345, 350 AVERAGE

	FORD FAC. FILL	2 x 30		
OIL GRADE	30	1x10W20	10W20	10W20
km	6339	11342	16780	23661
Date				
TANe mgKOH/g D-664	3.51	4.12	3.47	4.07
TBNe mgKOH/g D-2896	13.9	14.6	14.1	9.7
Fuel Dilution D-322	0.4	0.3	0.2	0.1
Visc. @100°C	10.48	9.6	8.08	8.06
Pentane Insols. D-893	<0.43	0.55	0.27	0.27
Al	11.6	21.4	22.5	24.8
Cr	4.2	4.9	8.9	8.8
Cu	38.4	101.0	68.6	112.0
Fe	60.3	116.5	60.3	58.6
Pb	140.0	92.0	81.1	54.1
Si	65.7	41.3	21.2	16.9
Pour Point °C	-36	-36	-47	-45
Flash Point °C	221	217	219	220
Km on Oil	6339	6000	4898	6881
Oil Consumption, L/drain	1.0	0.0	0.5	0.5
Notes	5 cars	3 cars 342 343 350	2 cars 342 343	2 cars 342 343

Table 13/ Methanol Fleet Used-Oil Analysis -- Ford Cars

337, 338, 339, 340 AVERAGE (NORMAL SERVICE)

OIL GRADE	30	10W20	10W20	10W20	10W20	10W20	10W20	10W20(3) 15W30(1)	15W30	15W30
km	1051	2016	3001	4188	5019	6201	11075	16195	21168	26351
Date										
TANe mgKOH/g D-664	3.60	-	-	-	-	3.65	3.85	3.27	3.67	3.54
TBNe mgKOH/g D-2896	18.0	-	-	-	-	13.3	12.9[1]	12.2	14.7	13.8
									7.8[1]	5.5
Fuel Dilution D-322	0.2	-	-	-	-	0.28	0.18	0.1	0.2	0.3[1]
Visc. @100°C	-	7.78	-	7.45	7.70	7.57	7.71[1]	7.78[1]	9.87[1]	10.4[2]
Pentane Insols. D-893	0.3	0.2	0.26	0.24	0.39	0.40	0.36	0.34	0.33	0.49
Al	20.9	6.7	11.9	12.6	15.1	18.1	16.4	12.7	8.9	11.7
Cr	2.0	1.3	2.4	3.7	4.9	8.0	7.2	4.3	1.2	4.5
Cu	17.2	5.1	18.2	30.7	36.2	48.2	66.4	55.7	20.2	13.5
Fe	49.4	16.2	29.9	39.9	51.3	64.2	53.8	35.6	25.0	48.7
Pb	133.3	45.5	79.8	118.9	111.2	130.7	95.9	49.7	29.1	22.9
Si	86.7	36.3	45.2	52.5	45.1	44.4	19.5	10.6	7.1	21.8
Pour °C	-37	-	-	-	-	-45	-46	-45[1]	-43[1]	-
Flash °C	211	-	-	-	-	+192	+218	221	224[1]	-
Km on Oil	1051	965	1950	3137	3968	5150	4874	5120	4973	5183
Oil Consumption, L/drain	0.0	-	-	-	-	0.1	0.4	0.3	0.4	0.3
Notes						Drain	Drain 1=3 cars	Drain 1=3 cars	Drain 1=3 cars	Drain 1=3 cars 2=1 car

Table 14/ Methanol Fleet Used-Oil Analysis -- Other Cars

OIL GRADE	3 x 30 1 x 10W20
km	5819
Date	
TANe mgKOH/g D-664	3.09
TBNe mgKOH/g D-2896	15.4
Fuel Dilution D-322	0.5
Visc. @100°C	9.47
Visc. @ 40°C	-
Pentane Insols. D-893	0.71
Al	28.3
Cr	3.4
Cu	22.3
Fe	49.5
Pb	328.0
Si	49.7
Pour Point °C	-38
Flash Point °C	215
Km on Oil	4720
Oil Consumption, L/drain	?

- 4 Car Avg.

Table 15/ Engine Ratings

	AUNT MINNIE SERVICE					NORMAL SERVICE				
	333	334	335	336		337	338	339	340	
Sludge Deposits										
Rocker Arm Cover	9.88	9.77	9.82	9.75	9.81	9.90	9.75	9.75	9.75	9.79
Front Seal Housing	9.85	9.90	9.88	9.75	9.85	9.75	9.88	9.90	9.92	9.86
Oil Pan	9.54	9.25	9.75	9.75	9.57	9.75	9.75	9.67	9.65	9.71
Valve Deck	9.88	9.85	9.88	9.75	9.84	9.88	9.81	9.81	9.79	9.82
Block Underside	9.85	9.80	9.88	9.90	9.86	9.75	9.75	9.75	9.75	9.75
Sludge	9.80	9.72	9.84	9.78	9.79	9.81	9.79	9.78	9.77	9.79
Varnish Deposits										
Piston Skirts	9.30	9.16	9.33	9.61	9.35	9.23	9.36	9.25	9.25	9.27
Rocker Arm Cover	8.53	9.26	9.35	9.47	9.15	9.41	9.00	8.79	8.91	9.03
Cylinder Wall	9.42	9.36	9.08	9.70	9.39	9.44	9.21	9.11	9.11	9.22
Oil Pan	9.58	8.94	9.07	9.11	9.18	8.86	8.67	8.86	9.23	8.91
Varnish	9.21	9.18	9.20	9.47	9.27	9.23	9.06	9.00	9.12	9.10
Clogging										
Oil Ring, %	0	0	0	0	0	0	0	0	0	0
Oil Screen, %	0	0	0	0	0	0	0	0	0	0
Stuck Comp. Rings, no.	0	0	0	0	0	0	0	0	0	0
Stuck Oil Rings, No1.	0	0	0	0	0	0	0	0	0	0
Stuck Lash Adj. Bodies, no.	0	0	0	0	0	0	0	0	0	0
Stuck Lash Adj. plungers, no.	0	0	0	0	0	0	0	0	0	0

Table 16/ Engine Ratings

	AUNT MINNIE SERVICE					NORMAL SERVICE				
	333	334	335	336		337	338	339	340	
Intake Valve Deposits										
1	9.0	8.5	9.0	9.5	9.0	9.3	9.0	9.7	8.5	9.1
2	8.5	8.8	8.0	9.3	8.7	8.8	9.0	9.3	8.8	9.0
3	8.8	8.5	8.5	9.3	8.8	9.0	9.0	9.0	8.8	9.0
4	9.0	8.3	9.0	9.3	8.9	9.0	9.0	9.3	9.0	9.1
	8.8	8.5	8.6	9.4	8.8	9.0	9.0	9.3	8.8	9.0
Intake Valve Deposit wts. g										
1	0.329	0.518	0.144	0.152	0.286	0.232	0.574	0.223	0.337	0.342
2	0.394	0.237	0.225	0.300	0.289	0.332	0.194	0.196	0.203	0.231
3	0.247	0.275	0.167	0.272	0.240	0.359	0.357	0.268	0.190	0.294
4	0.218	0.340	0.160	0.265	0.246	0.352	1.571	0.254	0.289	0.617
	0.297	0.343	0.174	0.247	0.265	0.319	0.674	0.235	0.255	0.371
Exhaust Valve Deposits, g										
1	0.273	0.201	0.154	0.172	0.200	0.377	1.164	0.465	0.678	0.671
2	0.266	0.151	0.119	0.132	0.167	0.379	0.338	0.289	0.327	0.333
3	0.193	0.164	0.164	0.175	0.174	0.458	0.452	0.373	0.355	0.410
4	0.209	0.200	0.166	0.142	0.179	0.402	0.895	0.287	0.411	0.499
	0.235	0.179	0.151	0.155	0.180	0.404	0.712	0.354	0.443	0.478

Table 17/ Engine Wear Results

		AUNT MINNIE SERVICE			NORMAL SERVICE		
WEAR OF COMPONENTS		335	336		339	336	
Cyl. Dia. Long	Ins.	0.0001	0.0001	0.0001	0.0006	0.0002	0.0004
Trans	Ins.	0.0002	0.0001	0.0002	0.0008	0.0003	0.0006
Piston Skirt Dia.	Ins.	0.0003	0.0003	0.0003	0.0002	0.0007	0.0005
Ring Gap Growth (top)	Ins.	-0.0010	+0.0020	0.0005	0.0020	0.0050	0.0035
(middle)	Ins.	+0.0020	+0.0010	0.0015	0.0040	0.0030	0.0035
Ring Side Clearance (top)	Ins.	0.0010	0.0010	0.0010	0.0005	0.0004	0.0005
(middle)	Ins.	0.0002	0.0000	0.0001	0.0005	0.0001	0.0003
Valve Lifter HT (I)	Ins.	0.0004	0.0016	0.0010	0.0005	0.0013	0.0009
(E)	Ins.	0.0005	0.0009	0.0007	0.0004	0.0004	0.0004
Valve Stem Dia. (I)	Ins.	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000
(E)	Ins.	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000
Valve Guide In.Dia. (I)	Ins.	0.0002	0.0003	0.0003	0.0004	0.0005	0.0005
(E)	Ins.	0.0003	0.0003	0.0003	-0.0002	0.0007	0.0003
Camshaft Lobe (I)	Ins.	0.0003	0.0018	0.0011	0.0005	0.0009	0.0007
(E)	Ins.	0.0003	0.0015	0.0009	0.0004	0.0009	0.0007
Valve Tip ht. (I)	Ins.	0.0005	0.0020	0.0013	+0.0007	-0.0003	0.0002
(E)	Ins.	0.0004	0.0010	0.0007	+0.0002	-0.0010	0.0001
Brngs. - Con Rod	Ins.	0.0001	0.0002	0.0002	0.0002	0.0002	0.0002
- Mains	Ins.	0.0001	0.0002	0.0002	0.0002	0.0001	0.0001
Other Remarks:		- Crankshaft Journals Stained - Camshaft Lobes Rusted - Lifters Stained - Cyl. Bore Rust (slight)	- Crankshaft Journals Stained - Camshaft Lobes Rusted - Lifters Stained - Cyl. Bore Rust (slight)		- Crankshaft Journals Stained - Camshaft Lobes Rusted - Lifters Stained - Cyl. Bore Rust (slight)	- #1 cyl. bore scored - Crankshaft Journals Stained - Camshaft Lobes Rusted - Lifters Stained - Cyl. Bores Rusted	

Table 18/ Engine Wear Results

			335	336	Avg.	339	340	Avg.
Ring Wt. Loss	Top	g	0.0029	0.0119	0.0074	0.0205	0.0703	0.0454
	Middle	g	0.0095	0.0107	0.0101	0.0103	0.0289	0.0196
Ring Wt. Cleaned Loss	Top	g	0.0082	0.0145	0.0114	0.0210	0.0706	0.0458
	Middle	g	0.0114	0.0138	0.0126	0.0132	0.0293	0.0213
Rod Brng. Wt. Loss	Top	g	0.0145	0.0134	0.0140	0.0150	0.0222	0.0186
	Btm.	g	0.0055	0.0045	0.0050	0.0062	0.0052	0.0057
	Btm.	g	0.0200	0.0179	0.0190	0.0212	0.0274	0.0243
Main Brng. Wt. Loss	Top	g	0.0852	0.0583	0.0718	0.0744	0.0735	0.0740
	Btm.	g	0.0169	0.0083	0.0126	0.0100	0.0132	0.0116
	Btm.	g	0.1021	0.0666	0.0844	0.0844	0.0867	0.0856
Rocker Arm Wt.	(I)	g	0.0083	0.0058	0.0071	-0.0235●	0.0050	-0.0093●
Loss	(E)	g	0.0117	0.0073	0.0095	-0.0204●	0.0061	-0.0072●
Rocker Arm Pivot Wt.	(I)	g	0.0147	-0.0196●	-0.0025●	-0.0503●	0.0376	0.0064
Loss	(E)	g	0.0409	-0.0250●	+0.0080	-0.0497●	0.0423	-0.0037●

● Possible fuel absorption by sintered metal part

Table 19/ Fuel Blends and Inspection Properties

Fuel Blend No.	A	B	C	D	E
Components:					
Methanol, %mass	100.0	90.6	88.4	86.3	85.5
SNL-W , %mass	-	9.4	9.2	8.9	8.9
DME, , %mass	-	-	2.4	4.8	5.6
Density kg/L	0.797	0.791	0.788	0.786	0.784
Carbon, %mass	37.6	42.6	41.6	41.7	41.8
RVP, dry, kPa	32.0	48.3	75.8	91.0	100.0
D-86 Distillation					
IBP, °C	64	48	41	36	26
10%, °C	64	62	60	57	61
50%, °C	64	64	64	64	64
90%, °C	64	64	64	64	-
EP, °C	64	65	66	67	-
% recovery	99.5	98.7	97.1	95.5	-•
Latent heat of evap. @0°C, MJ/L (calculated)	0.996	0.937	0.919	0.902	0.895

• Test terminated due to no meniscus movement, approximately 90% recovery

Table 20/ Base Component Inspection Properties

	Methanol	Super Non-leaded Gasoline (Winter Grade)	DiMethyl Ether
Chemical Formula	CH_3OH	C_8H_{15}●	CH_3OCH_3
Net Heating Value MJ/L	15.9	32.3	
Density, Kg/L	0.797	0.743	0.661
Molecular Weight	32.04	111[1]	46.07
Dry Reid Vapor Pressure, KPa	32.0	96.0	~850
% Carbon by mass	37.6	86.5	52.1
RON	111	96.5	?
MON	90	86.6	?
D-86 Distillation			
IBP, °C	64	28	-25
10%, °C	64	41	-
50%, °C	64	103	-
90%, °C	64	153	-
EP , °C	67	199	-
% Recovery	99.8	95.4	-
Latent heat of evap. @0°C, MJ/L (calculated)	0.996	0.408	0.300

● Typical values

Table 21/ Cold Weather Driveability Results

Test Temp. °C	Car No.	FUEL A Test Temp.	A Total Demerits	B Test Temp.	B Total Demerits	C Test Temp.	C Total Demerits	D Test Temp.	D Total Demerits	E Test Temp.	E Total Demerits
-10	333	-	-	-5	310	-9	219	-8	175	-7	131
	334	-	-	-5	236	-12	236	-7	206	-11	143
	335	-	-	-5	161	-9	173	-8	199	-7	134
	337	-	-	-5	274	-9	214	-5	211	-11	161
	Avg.	-	-	-5	245	-10	211	-7	198	-9	142
+5	333	+6	420	+4	144	+3	135	+3	99	+7	35
	334	+6	340	+1	132	+3	57	+3	89	+7	43
	335	+6	361	+4	111	+3	35	+3	34	+7	13
	337	+6	365	+4	149	0	163	+3	86	+6	67
	Avg.	+6	372	+3	134	+2	98	+3	77	+7	40

All total demerits given are the average of two tests.

Table 22/ Equations Relating Driveability Demerits to Both Temperature and DME Content

Fuel 2: $DD = -12.8\ (Temp) + 178.4;\ R^2 = 0.62$
Fuel 3: $DD = -9.9\ (Temp) + 116.9;\ R^2 = 0.76$
Fuel 4: $DD = -11.5\ (Temp) + 114.4;\ R^2 = 0.84$
Fuel 5: $DD = -6.5\ (Temp) + 83.5;\ R^2 = 0.94$

All Fuels: $DD = -14.7\ (\%DME) - 2.8\ (Temp) + 174.6;\ R^2 = 0.73$

DD = Driveability Demerits
Temp. = Ambient Temperature, °C
%DME = % by mass DME in blend
R^2 = Square of correlation coefficient

Table 23/ Typical Gasoline Driveability Results on Commercially Available Winter Gasoline

Vehicle Type	Test Temperature, °C	Average Total Demerits
1982 Ford Escort	-10	42
	+5	28

Table 24/ Exhaust Emission Results

Nominal km	Blend Type	Car No.	Test Temp. °C	City Cycle Emissions, g/km HC	CO	NO_x
1 000	90/10+ 5 DME	339	+25	0.28	2.65	0.29
1 000	90/10+ 5 DME	340	+25	0.25	1.59	0.27
1 000		Average	+25	0.27	2.12	0.28
20 000	90/10+ 5 DME	339	+25	0.64	4.23	0.39
			+25	0.57	3.86	0.31
		Average		0.61	4.05	0.35
26 000	90/10+ 5 DME	340	+25	0.95	9.60	0.40
			+25	0.80	9.85	0.41
			+25*	0.59	6.69	0.40
23 000		Average†		0.60	5.37	0.38
1983 Canadian Standards for gasoline powered cars			+25	1.2	15.5	1.9
1983 California Standards for gasoline powered cars			+25	0.24●	4.3	0.43

* New catalyst installed
† Average of 339 average and +25[1] run on 340
● Non Methane standard

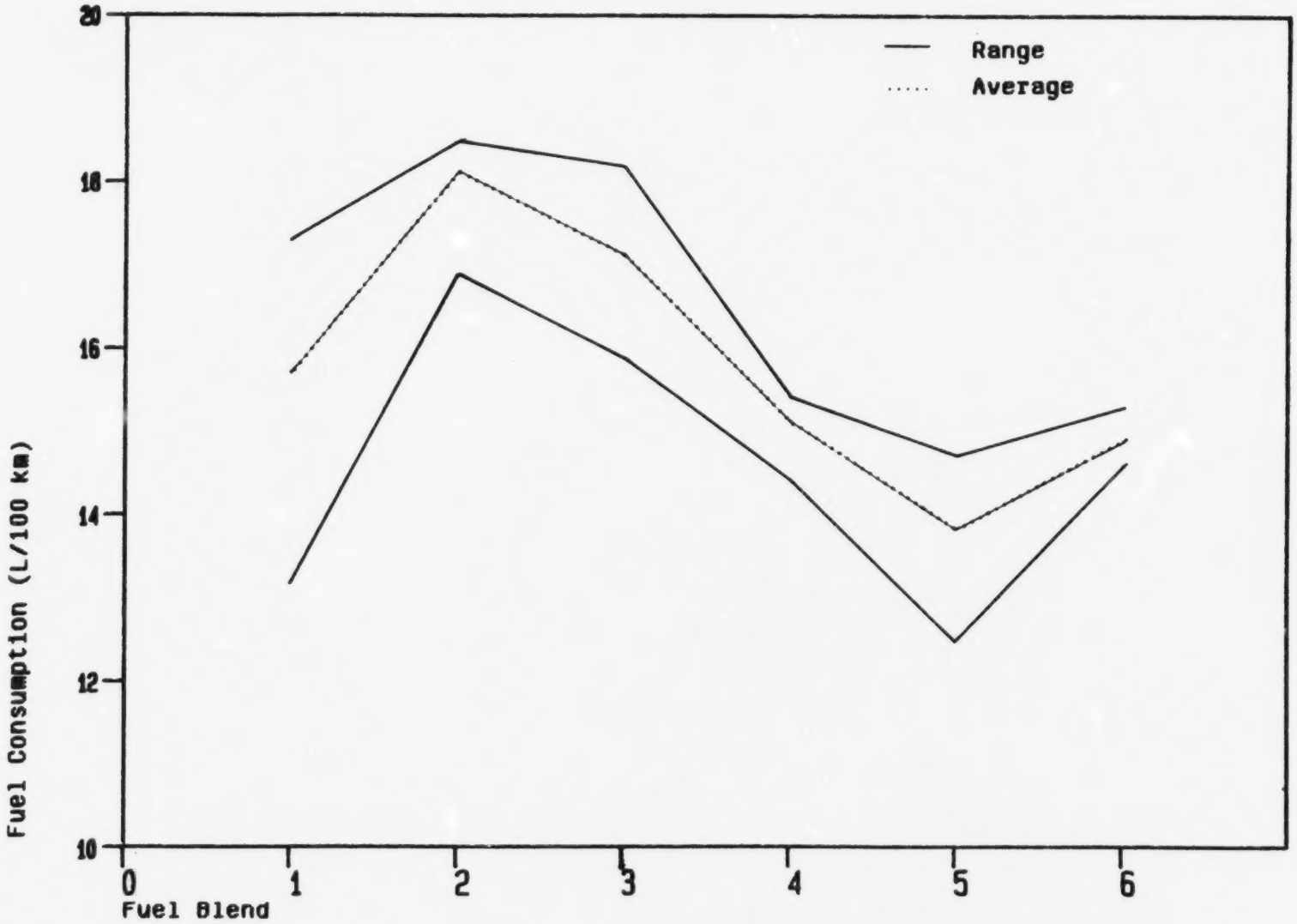


Figure 1/ Fuel Consumption of the Four Normal-Service Vehicles

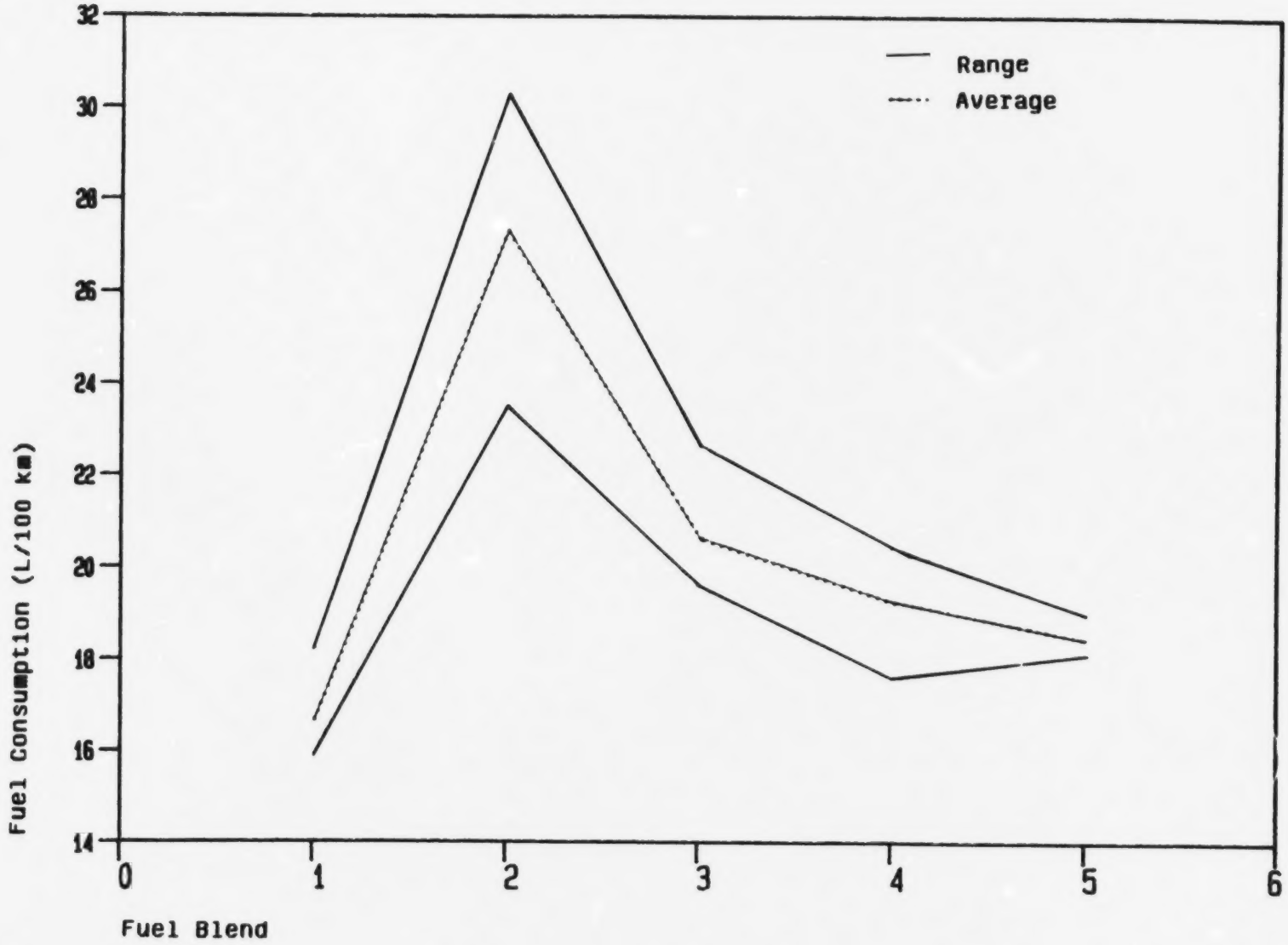


Figure 2/ Fuel Consumption of the Four Aunt Minnie Vehicles

Figure 3/ Fuel Consumption of the Five Ford Vehicles

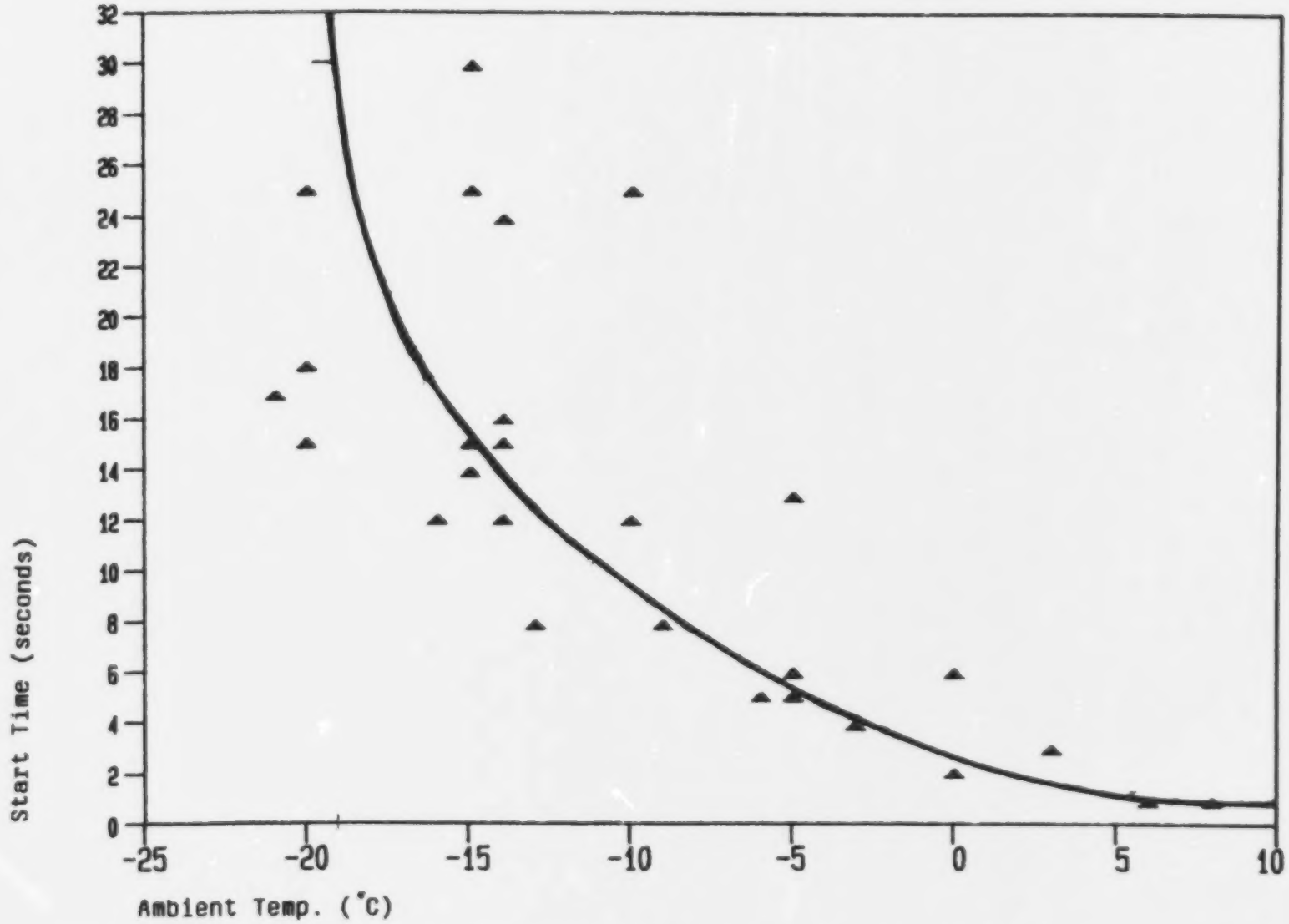


Figure 4/ Cold-Start Times vs. Temperature in the Four Normal-Service Vehicles

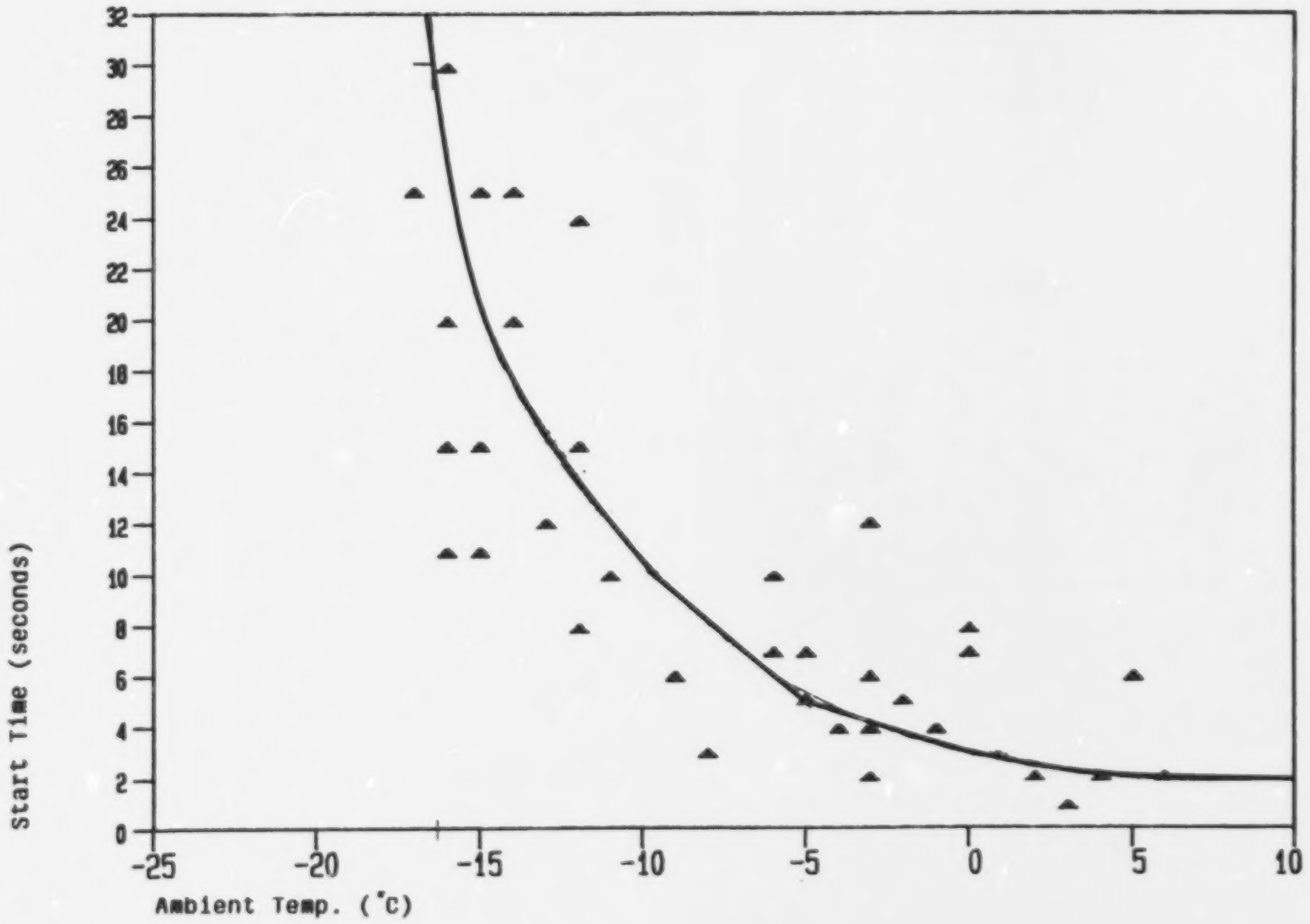


Figure 5/ Cold-Start Times vs. Temperature in the Four Aunt Minnie Vehicles

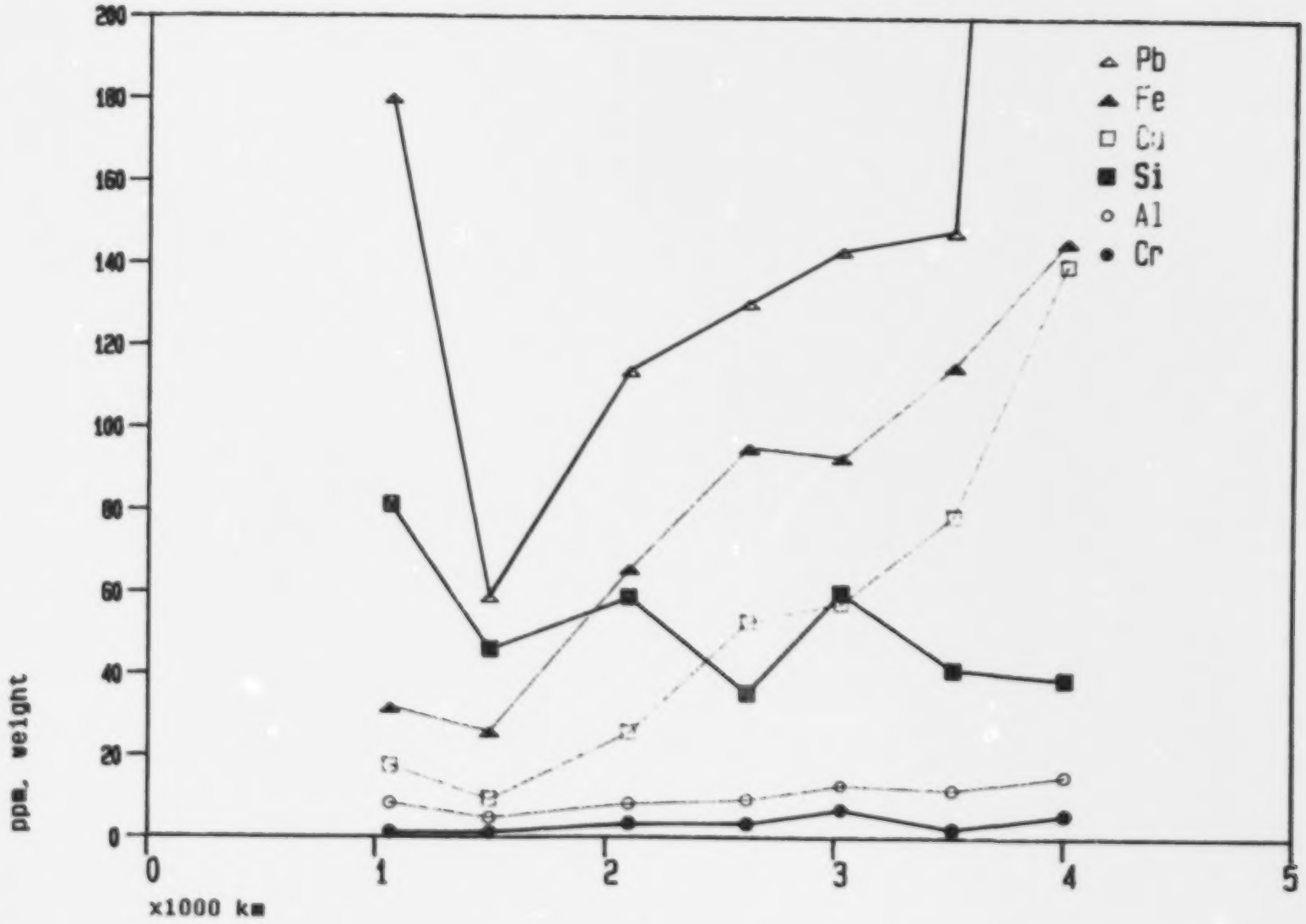


Figure 6/ Average Used-Oil Wear Metals in the Four Aunt Minnie Vehicles

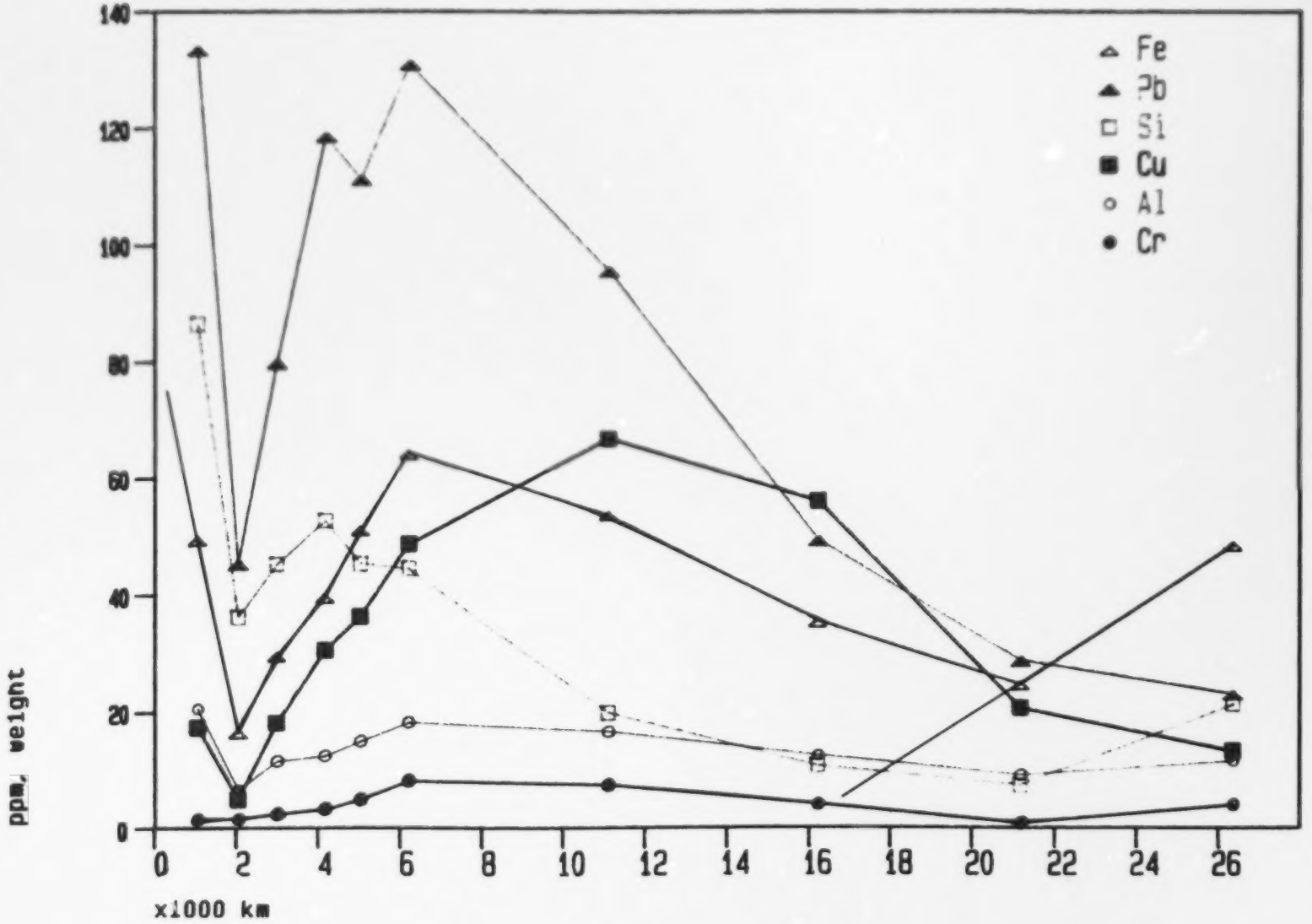


Figure 7/Average Used-Oil Wear Metals in the Four Normal-Service Vehicles

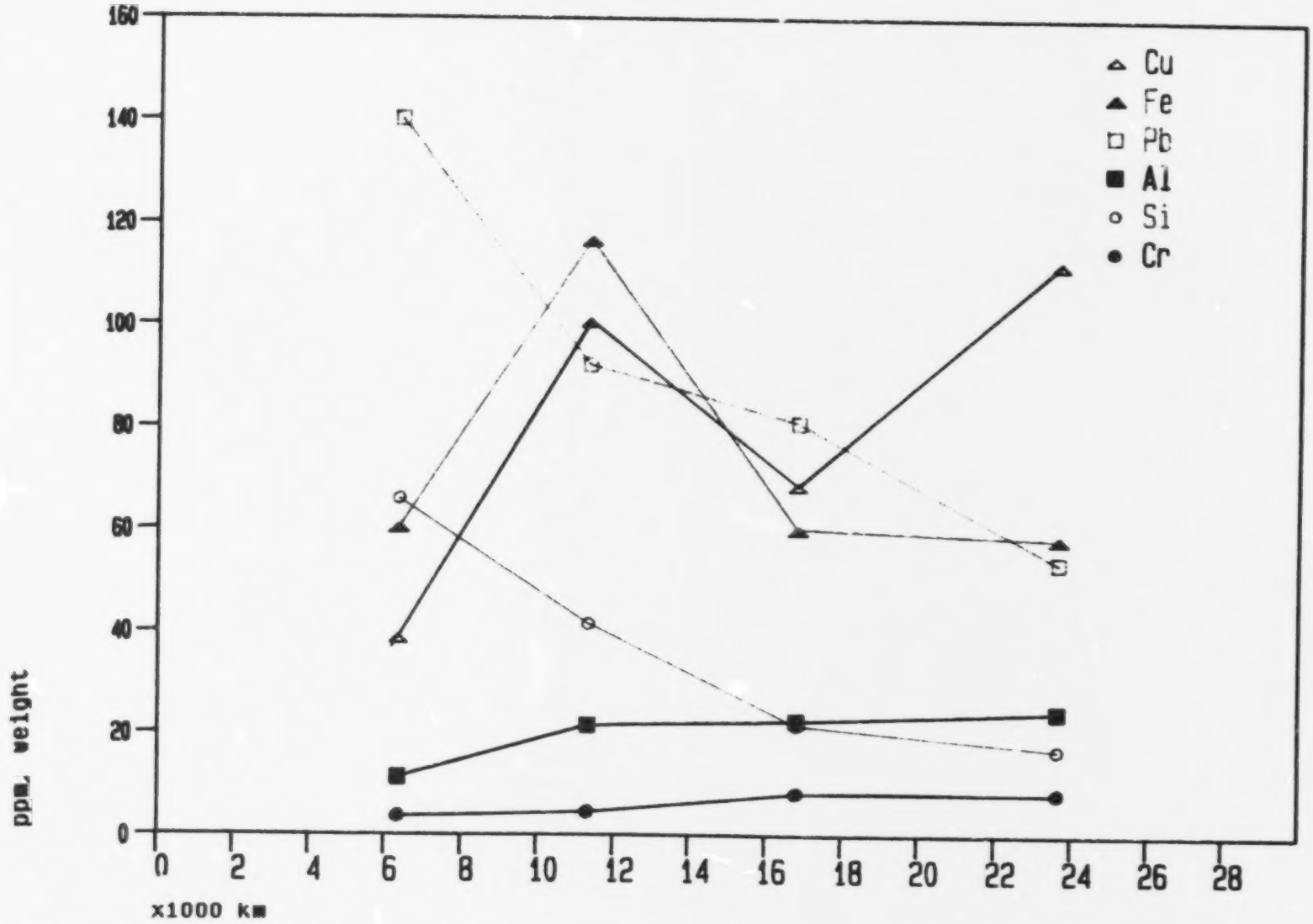


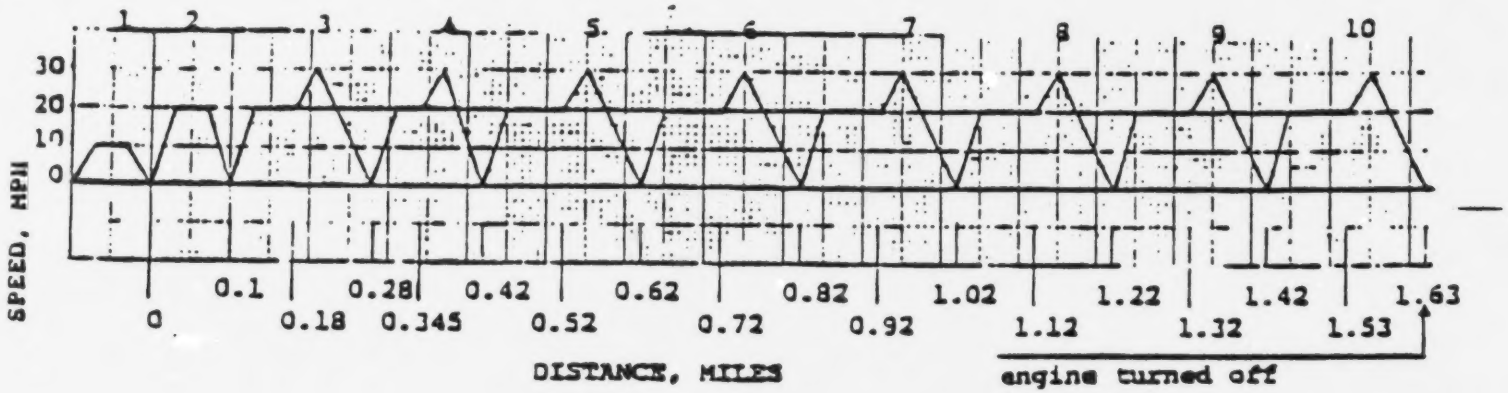
Figure 8/ Average Used-Oil Wear Metals in the Five Ford Vehicles

APPENDICES

APPENDIX A/ TEST VEHICLE IDENTIFICATION

TEST CAR NO.	LOCATION + SERVICE	LICENSE PLATE NO.	COLOUR	BODY STYLE	VIN
333	SHELL - AUNT MINNIE	VAB 233	RED	4 DR. HTCHBK.	1FABP1477DW243329
334	SHELL - AUNT MINNIE	VAB 234	LT. BLUE	4 DR. HTCHBK.	1FABP1473DW243330
335	SHELL - AUNT MINNIE	VAB 235	TAN	4 DR. HTCHBK.	1FABP1479DW243333
336	SHELL - AUNT MINNIE	VAB 236	YELLOW	4 DR. HTCHBK.	1FABP1475DW243331
337	SHELL - NORMAL SERVICE	VAB 237	WHITE	4 DR. HTCHBK.	1FABP1473DW243327
338	SHELL - NORMAL SERVICE	VAB 238	BLACK	4 DR. HTCHBK.	1FABP1471DW243326
339	SHELL - NORMAL SERVICE	VAB 239	DK. BLUE	4 DR. HTCHBK.	1FABP1477DW243332
340	SHELL - NORMAL SERVICE	VAB 240	PEWTER	4 DR. HTCHBK.	1FABP1475DW243328
329	FORD - FLEET SERVICE	_____	TAN	4 DR. HTCHBK.	2FABP1343DX126553
330	FORD - FLEET SERVICE	_____	LT. BLUE	4 DR. HTCHBK.	2FABP1345DX126554
331	FORD - FLEET SERVICE	_____	RED	4 DR. HTCHBK.	2FABP1340DX126834
342	R.M. BRIGHT	TML 613	TAN	4 DR. WAGON	1FABP1075DW243334
343	B. BLY	TMM 611	MAROON	4 DR. WAGON	1FABP1075DW243335
344	C. PHILLIPS	TMK 611	RED	4 DR. WAGON	1FABP1070DW242220
345	T. DOBSON	TML 992	LT. BROWN	4 DR. HTCHBK.	1FABP1075DW238226
350	B. SHADLOCK	VFL 648	ORANGE	4 DR. WAGON	1FABP1077DW243336

APPENDIX B/ COLD WEATHER DRIVEABILITY PROCEDURE



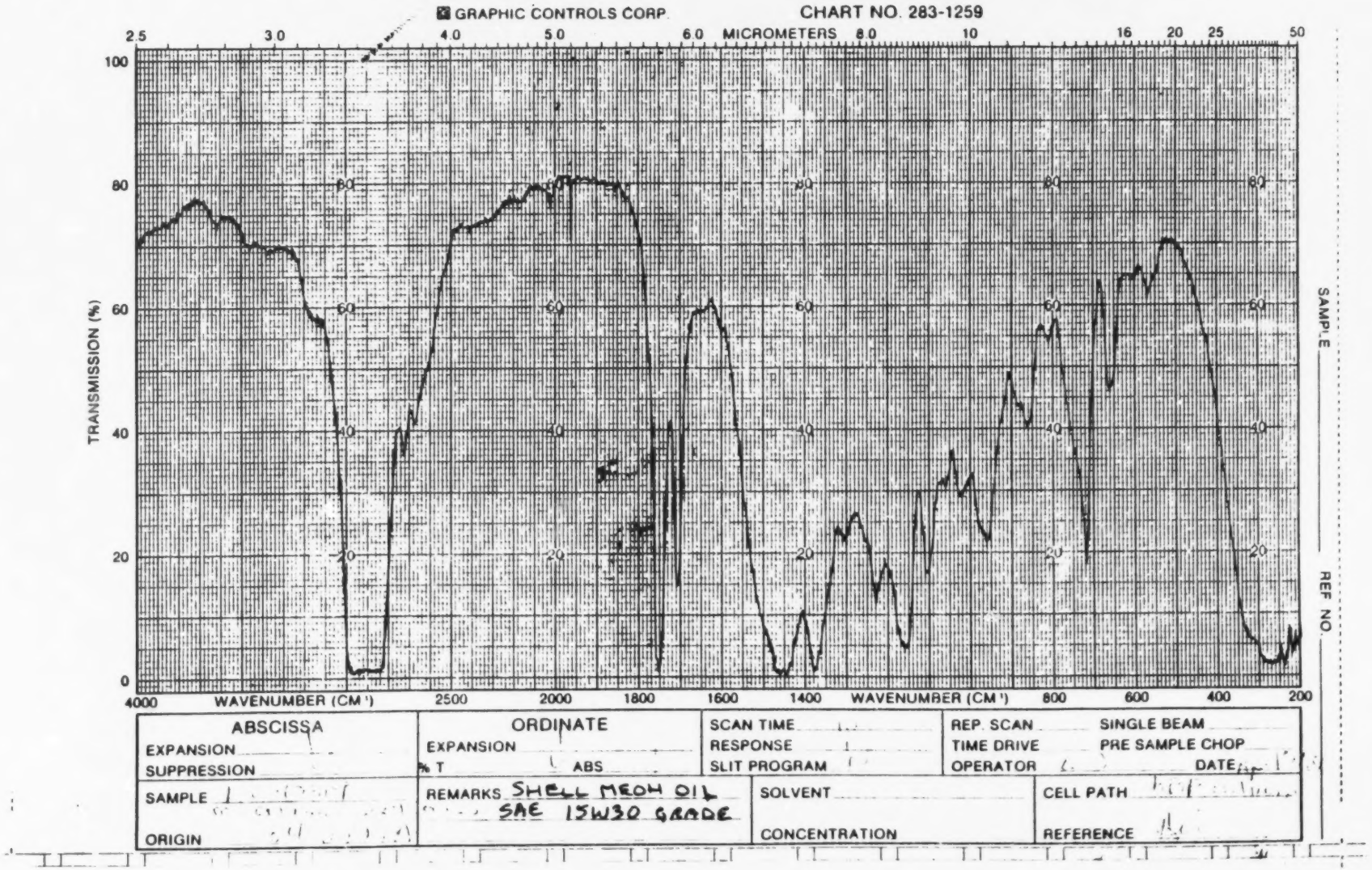
1. The engine is started according to the manufacturer's recommended starting procedure. It is allowed to idle for 10 sec. in neutral at fast idle, for 10 sec. in neutral at reduced rpm and for 10 sec. in a gear.

2. The initial driveaway (step 1) consists of a part throttle acceleration to 10 mph, a short cruise at that speed, deceleration to a full stop and a five sec. idle period.

3. The second driveaway mode (step 2) consists of a full throttle acceleration to 20 mph, a short cruise at that speed, deceleration to a full stop and a 5 sec. idle period.

4. Steps 3 - 10 are practically identical. They consist of a part throttle acceleration to 20 mph, a short cruise at that speed, a full throttle acceleration to 30 mph, a short cruise at that speed, deceleration to a full stop and a 5 sec. idle period.

APPENDIX C/ INFRARED SCANS OF NEW OILS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4.0
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6.0
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16
20
25
50
100
80
60
40
20
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WAVENUMBER (CM⁻¹)
2500
2000
1800
1600
1400
WAVENUMBER (CM⁻¹)
800
600
400
200
SAMPLE
REF NO.
ABSCISSA
EXPANSION
SUPPRESSION
ORDINATE
EXPANSION
%T
ABS
SCAN TIME
RESPONSE
SLIT PROGRAM
REP. SCAN
TIME DRIVE
OPERATOR
SINGLE BEAM
PRE SAMPLE CHOP
DATE
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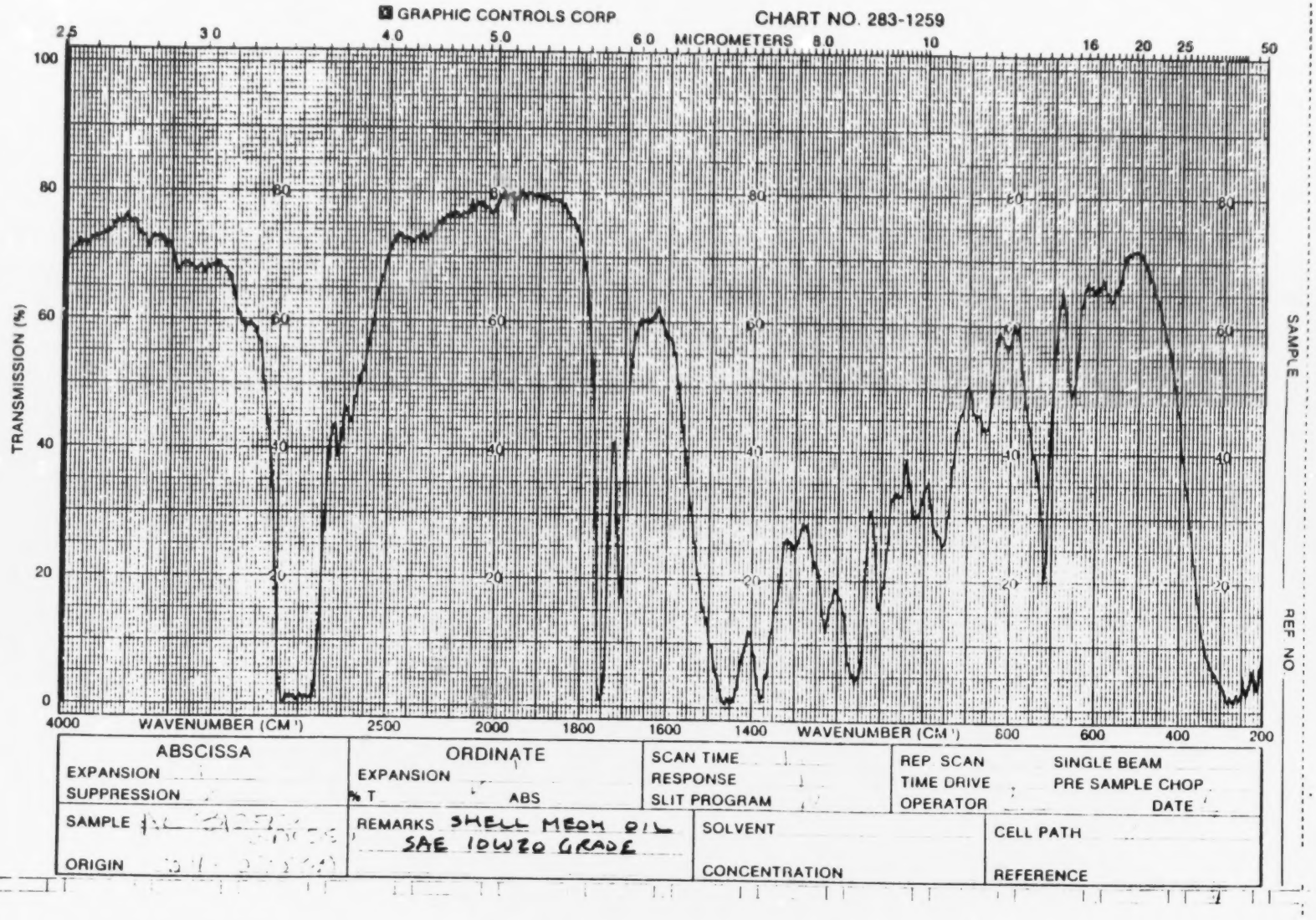
SAE 15W30 GRADE
SOLVENT
CONCENTRATION
CELL PATH
REFERENCE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5.0
6.0
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16
20
25
50
100
80
60
40
20
0
TRANSMISSION (%)
4000
WAVENUMBER (CM⁻¹)
2500
2000
1800
1600
1400
WAVENUMBER (CM⁻¹)
800
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200
SAMPLE
REF NO
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EXPANSION
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RESPONSE
SLIT PROGRAM
REP SCAN
TIME DRIVE
OPERATOR
SINGLE BEAM
PRE SAMPLE CHOP
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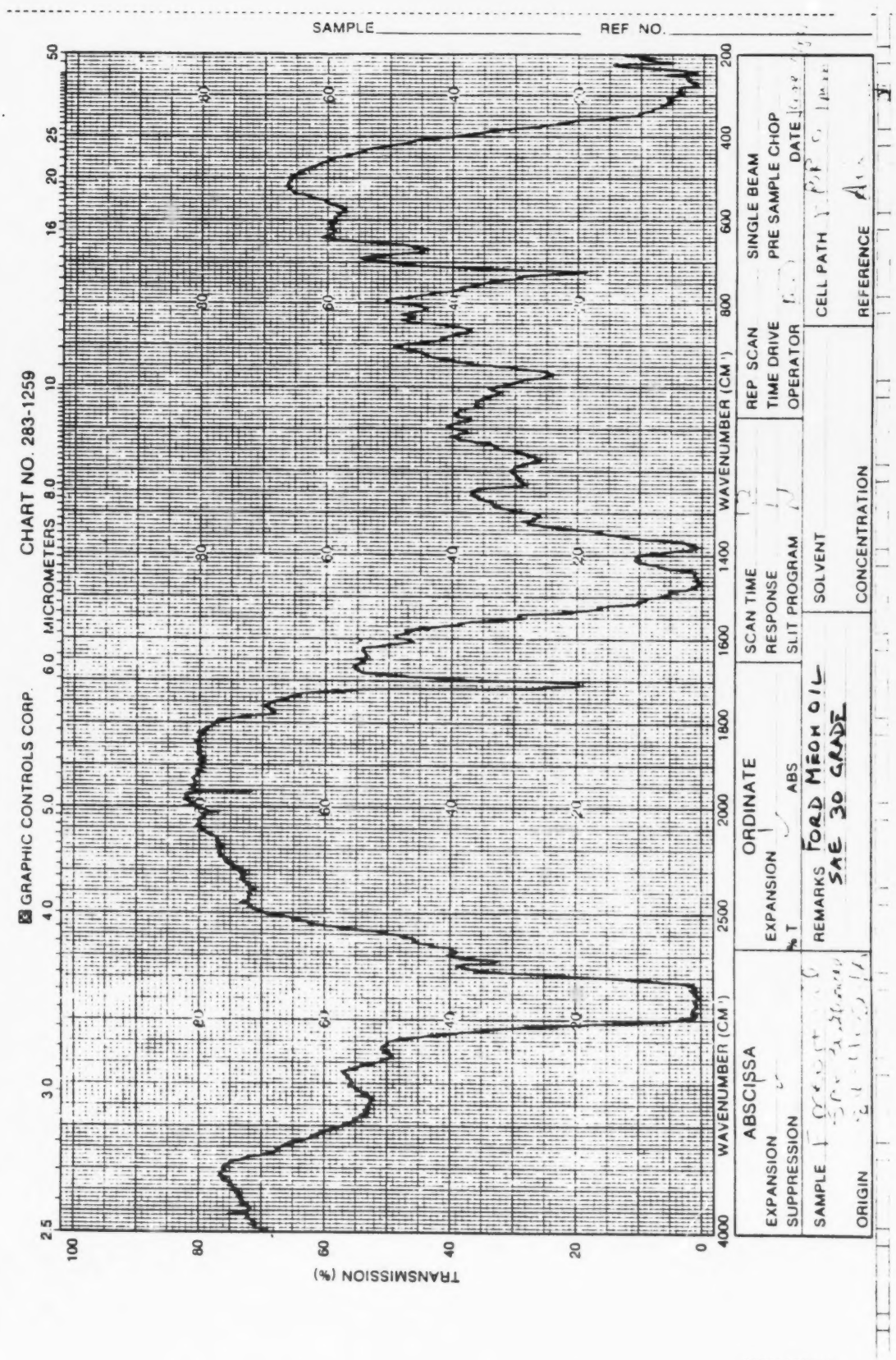
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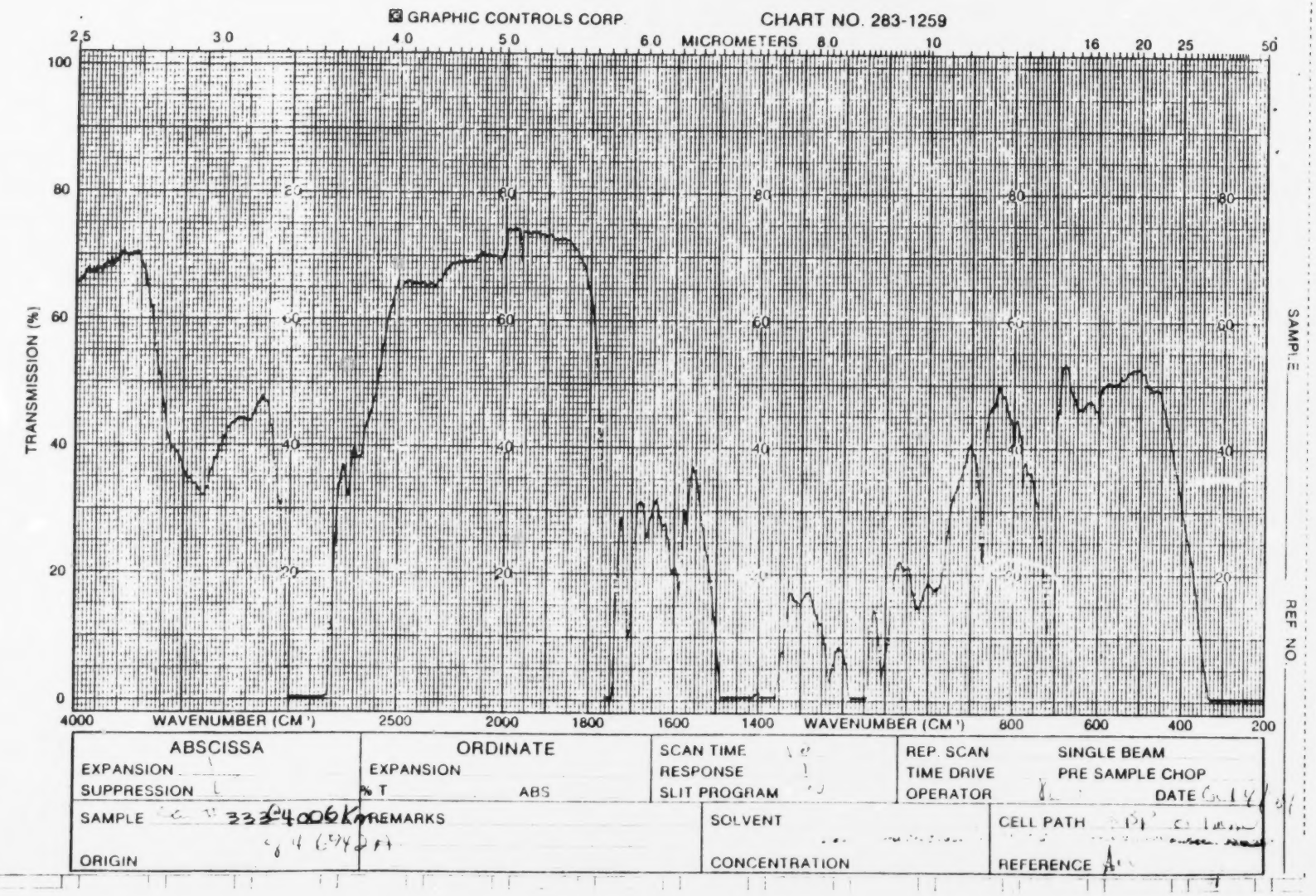
TRANSMISSION (%)
ABSCISSA
EXPANSION
SUPPRESSION
ORIGIN
ORDINATE
EXPANSION
%T
ABS
REMARKS FORD MEOH OIL
SAE 30 GRADE
SCAN TIME
RESPONSE
SLIT PROGRAM
SOLVENT
CONCENTRATION
REP SCAN
TIME DRIVE
OPERATOR
SINGLE BEAM
PRE SAMPLE CHOP
DATE
CELL PATH
REFERENCE

APPENDIX D/ INFRARED SCANS OF USED OILS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MICROMETERS
TRANSMISSION (%)
WAVENUMBER (CM⁻¹)
WAVENUMBER (CM⁻¹)
SAMPLE
REF NO.
ABSCISSA
EXPANSION
SUPPRESSION
ORDINATE
EXPANSION
% T
ABS
SCAN TIME
RESPONSE
SLIT PROGRAM
REP. SCAN
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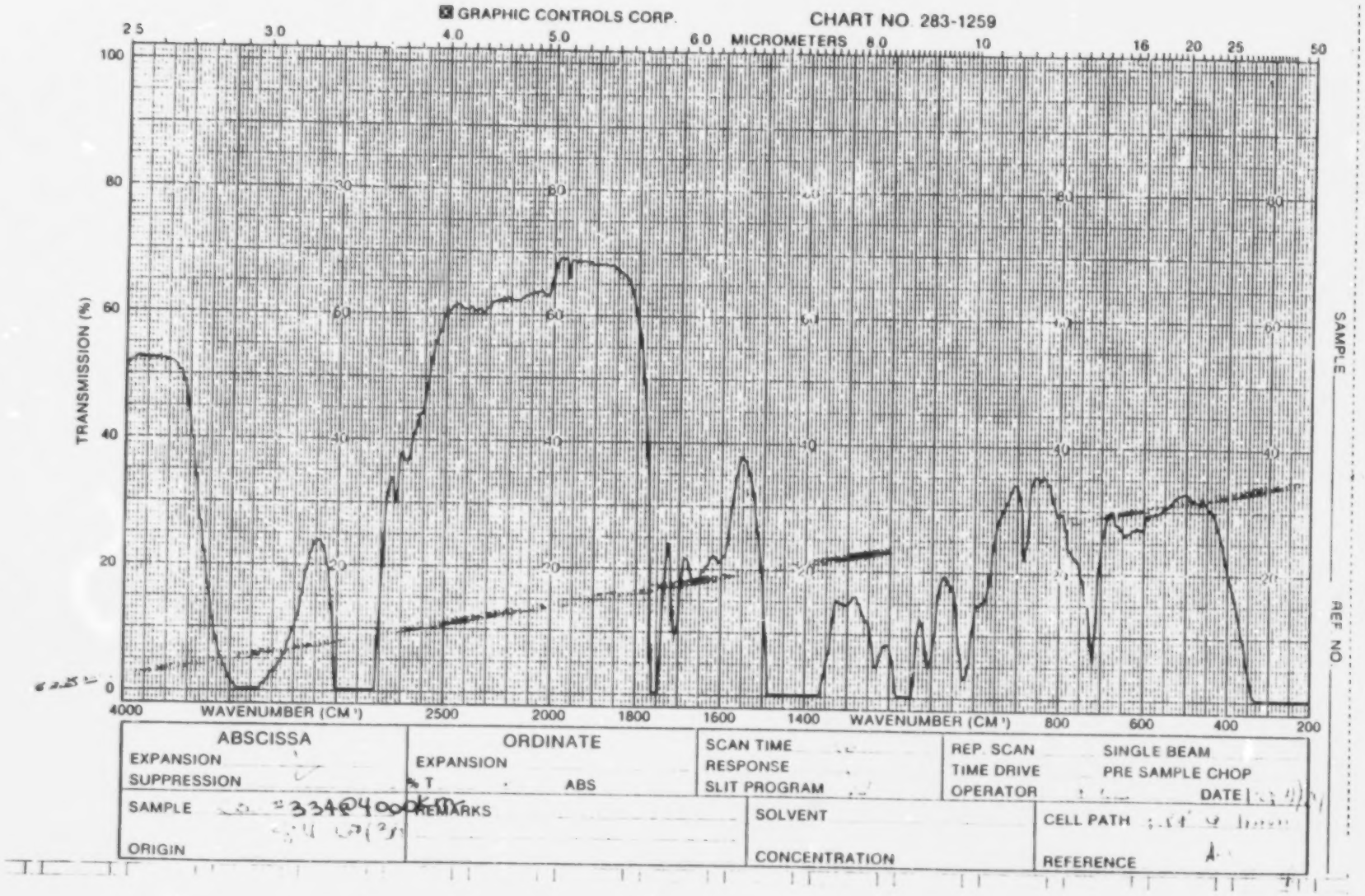
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6.0
MICROMETERS
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10
16
20
25
50
100
80
60
40
20
0
TRANSMISSION (%)
4000
WAVENUMBER (CM⁻¹)
2500
2000
1800
1600
1400
WAVENUMBER (CM⁻¹)
800
600
400
200
SAMPLE
REF NO.
ABSCISSA
EXPANSION
SUPPRESSION
ORDINATE
EXPANSION
%T
ABS
SCAN TIME
RESPONSE
SLIT PROGRAM
REP. SCAN
SINGLE BEAM
TIME DRIVE
PRE SAMPLE CHOP
OPERATOR
DATE
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REMARKS
ORIGIN
SOLVENT
CONCENTRATION
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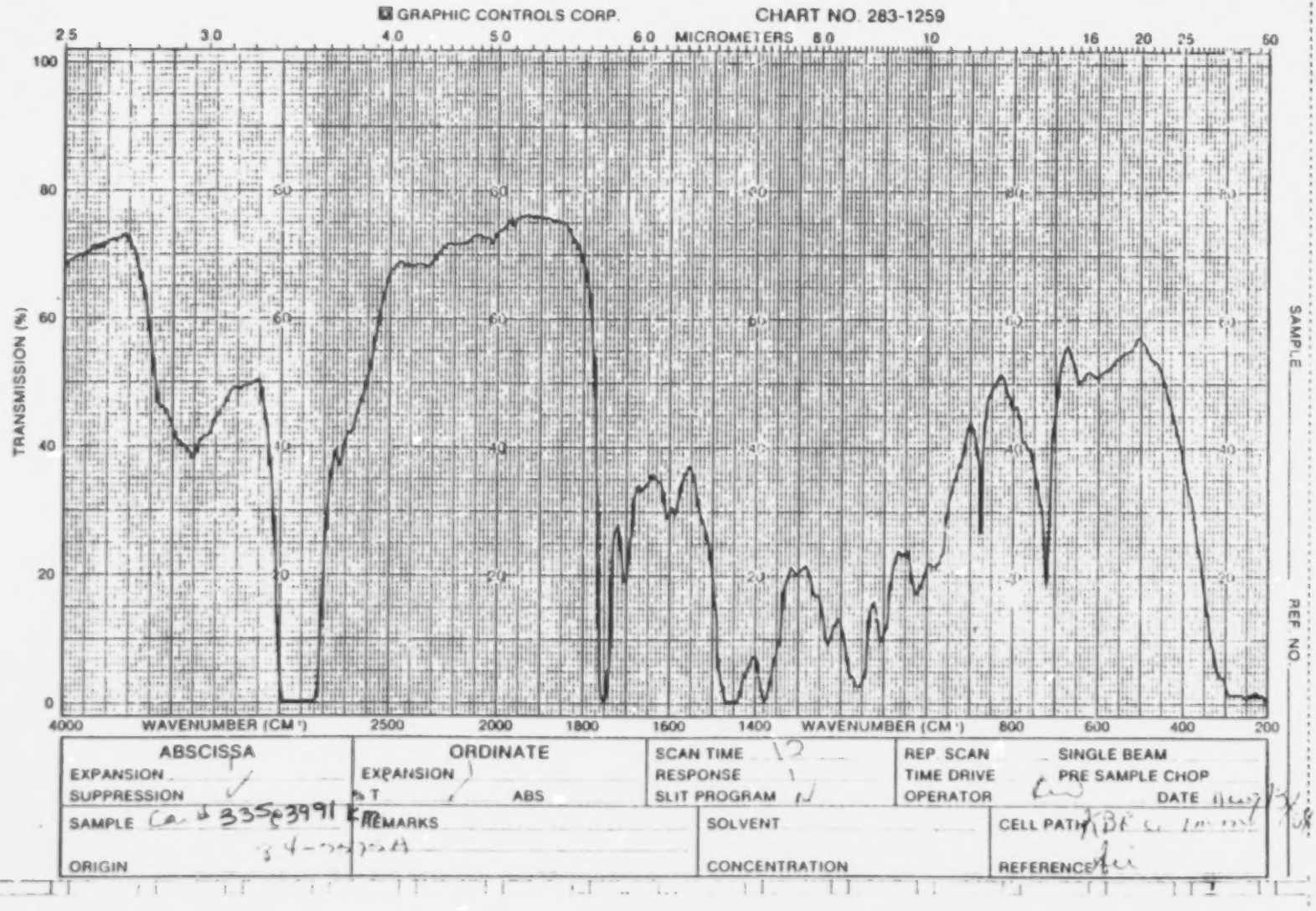
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TRANSMISSION (%)
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ABSCISSA
EXPANSION
SUPPRESSION
ORDINATE
EXPANSION
%T
ABS
SCAN TIME
RESPONSE
SLIT PROGRAM
REP SCAN
SINGLE BEAM
TIME DRIVE
PRE SAMPLE CHOP
OPERATOR
DATE
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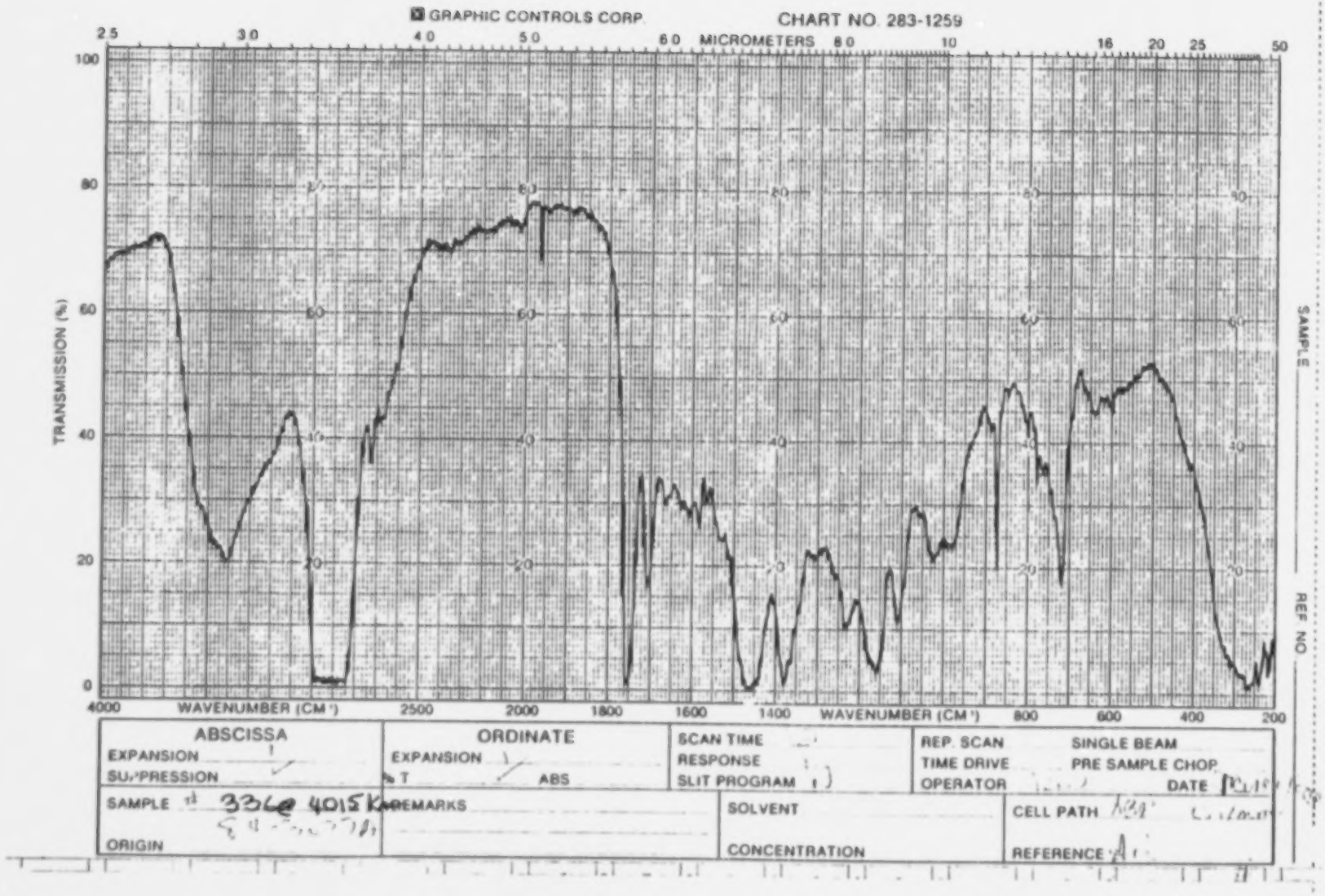
REMARKS
SOLVENT
CELL PATH
ORIGIN
CONCENTRATION
REFERENCE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4.0
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6.0
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16
20
25
50
100
80
60
40
20
0
TRANSMISSION (%)
4000
WAVENUMBER (CM⁻¹)
2500
2000
1800
1600
1400
WAVENUMBER (CM⁻¹)
800
600
400
200
SAMPLE
REF NO
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EXPANSION
SUPPRESSION
ORDINATE
EXPANSION
%T
ABS
SCAN TIME
RESPONSE
SLIT PROGRAM
REP. SCAN
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ORIGIN
CONCENTRATION
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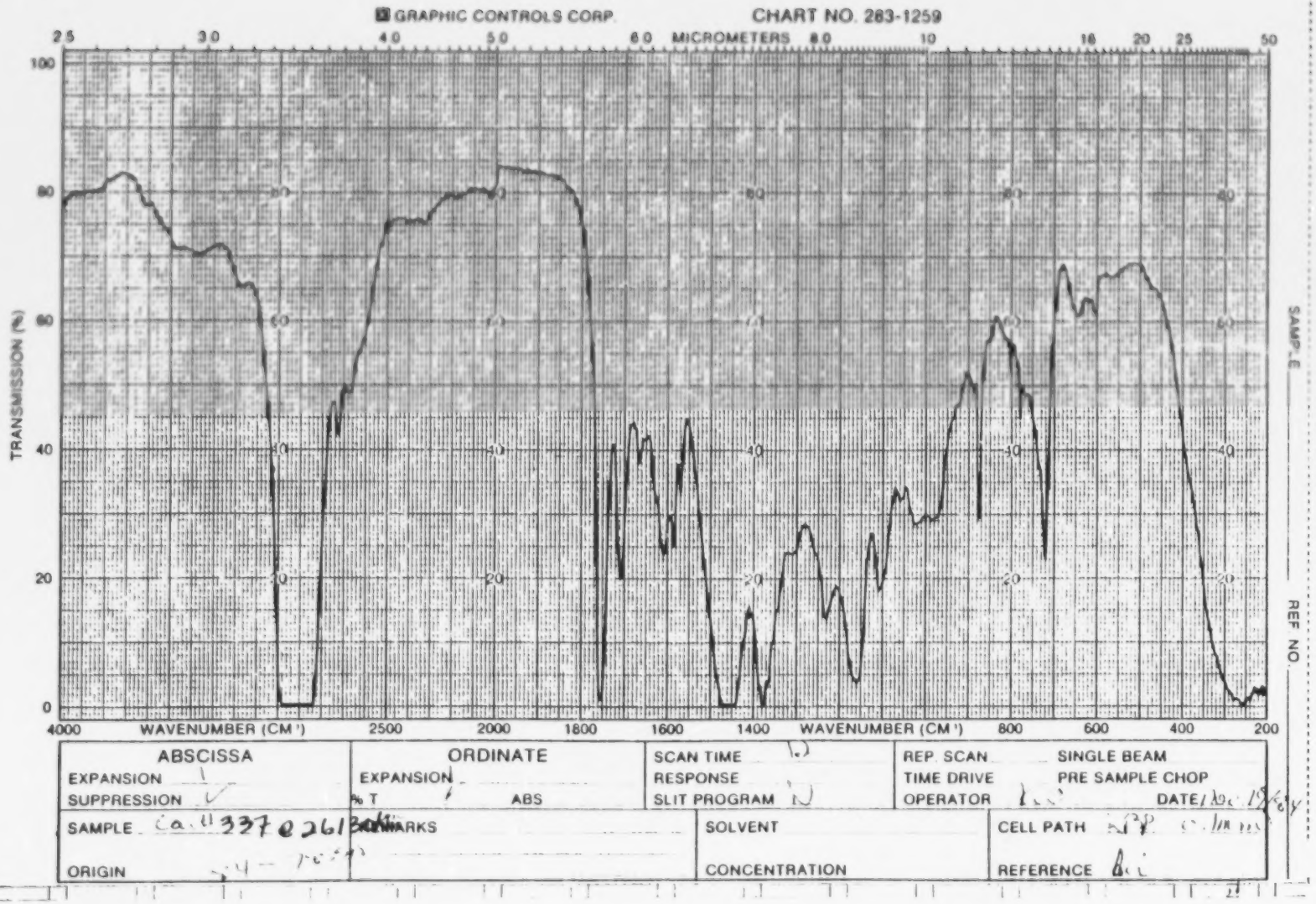
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WAVENUMBER (CM⁻¹)
SAMPLE
REF NO.
ABSCISSA
EXPANSION
SUPPRESSION
ORDINATE
EXPANSION
% T
ABS
SCAN TIME
RESPONSE
SLIT PROGRAM
REP. SCAN
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PRE SAMPLE CHOP
OPERATOR
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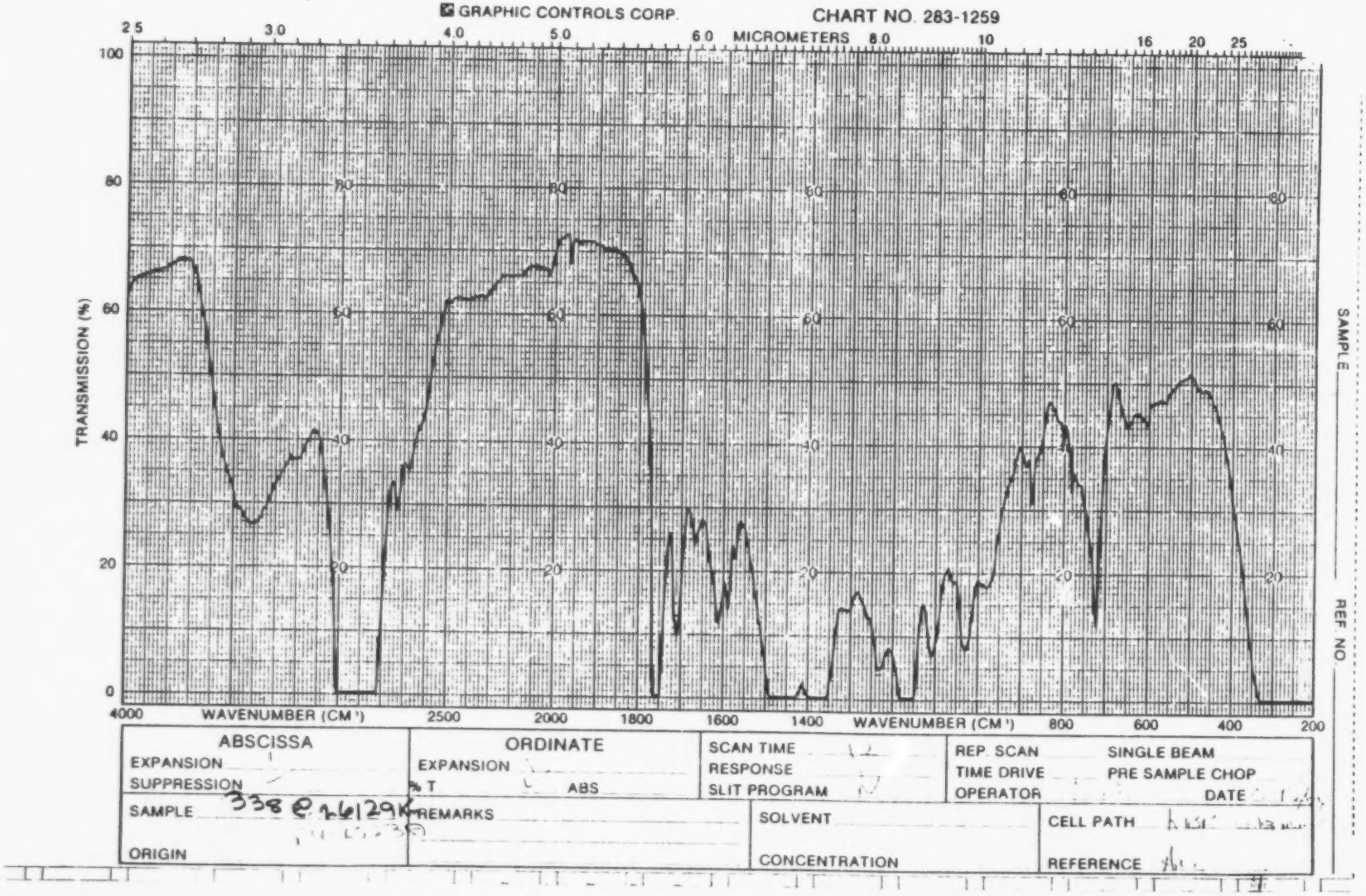
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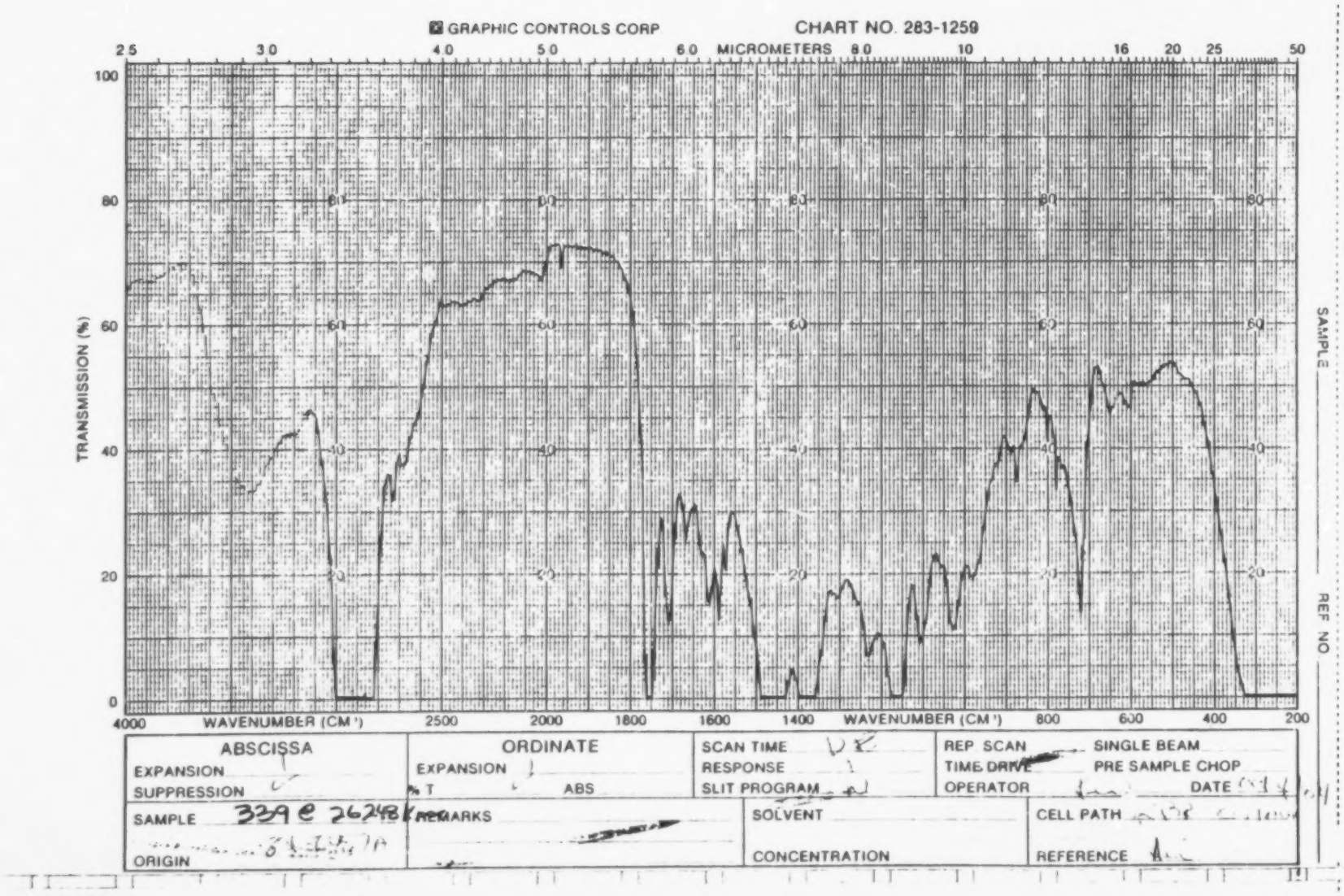
2.5
3.0
4.0
5.0
6.0
MICROMETERS
8.0
10
16
20
25
100
80
60
40
20
0
TRANSMISSION (%)
4000
WAVENUMBER (CM⁻¹)
2500
2000
1800
1600
1400
WAVENUMBER (CM⁻¹)
800
600
400
200
SAMPLE
REF. NO.
ABSCISSA
EXPANSION
SUPPRESSION
ORDINATE
EXPANSION
%T
ABS
SCAN TIME
RESPONSE
SLIT PROGRAM
REP. SCAN
SINGLE BEAM
TIME DRIVE
PRE SAMPLE CHOP
OPERATOR
DATE
SAMPLE
338 @ 26129K
REMARKS
SOLVENT
CELL PATH
ORIGIN
CONCENTRATION
REFERENCE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2.5 3.0 4.0 5.0 6.0 MICROMETERS 8.0 10 16 20 25 50
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TRANSMISSION (%)
4000 WAVENUMBER (CM') 2500 2000 1800 1600 1400 WAVENUMBER (CM') 800 600 400 200
SAMPLE
REF NO
ABSCISSA
EXPANSION
SUPPRESSION
ORDINATE
EXPANSION
% T ABS
SCAN TIME
RESPONSE
SLIT PROGRAM
REP SCAN SINGLE BEAM
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OPERATOR DATE
SAMPLE 339 @ 2624
ORIGIN
REMARKS
SOLVENT
CONCENTRATION
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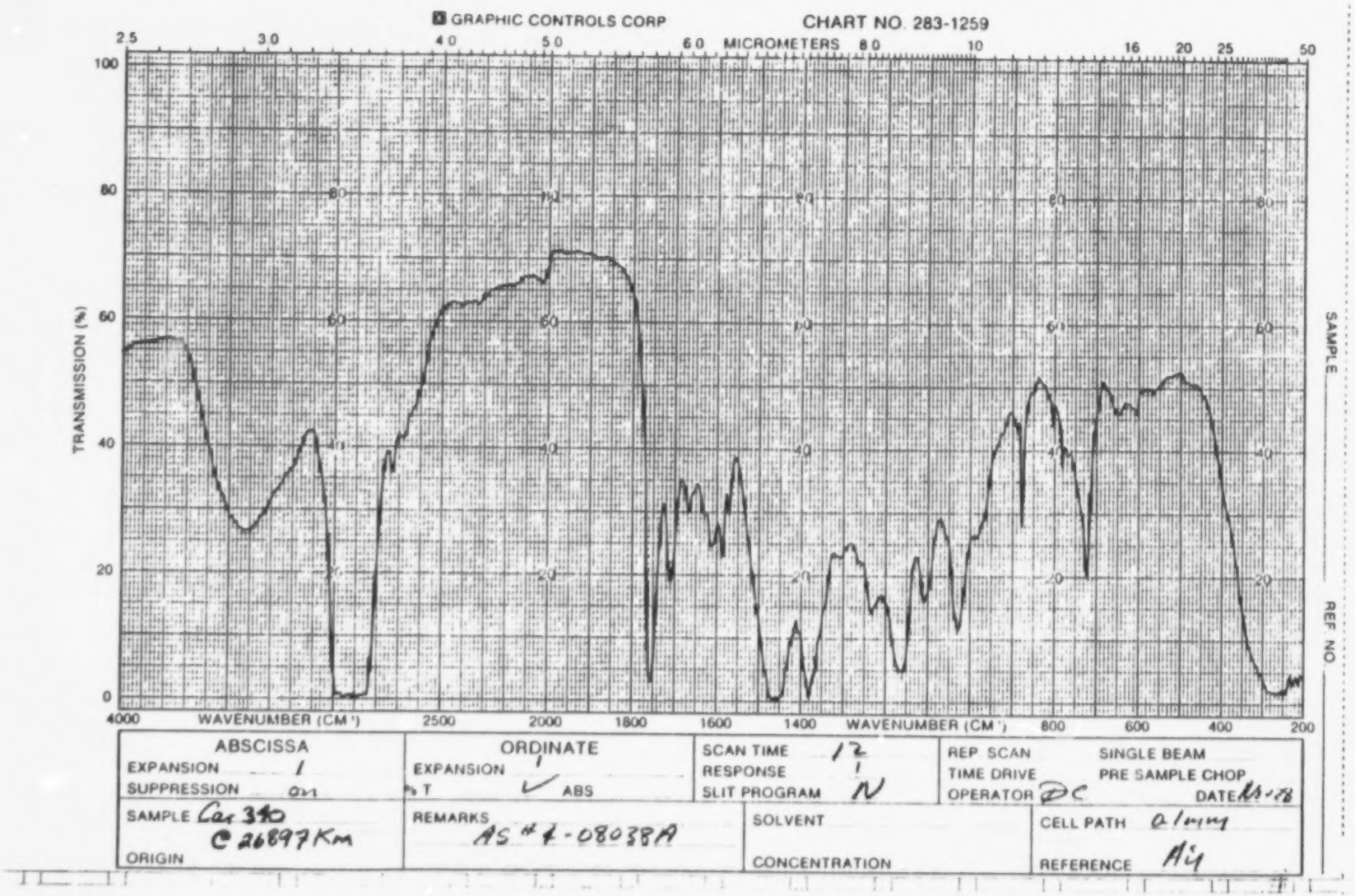
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TRANSMISSION (%)
4000 WAVENUMBER (CM⁻¹) 2500 2000 1800 1600 1400 WAVENUMBER (CM⁻¹) 800 600 400 200
SAMPLE
REF NO.
ABSCISSA
EXPANSION 1
SUPPRESSION on
ORDINATE
EXPANSION 1
%T ✓ ABS
SCAN TIME 12
RESPONSE 1
SLIT PROGRAM N
REP SCAN
TIME DRIVE
OPERATOR DC
SINGLE BEAM
PRE SAMPLE CHOP
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ORIGIN
REMARKS AS #1-08038A
SOLVENT
CONCENTRATION
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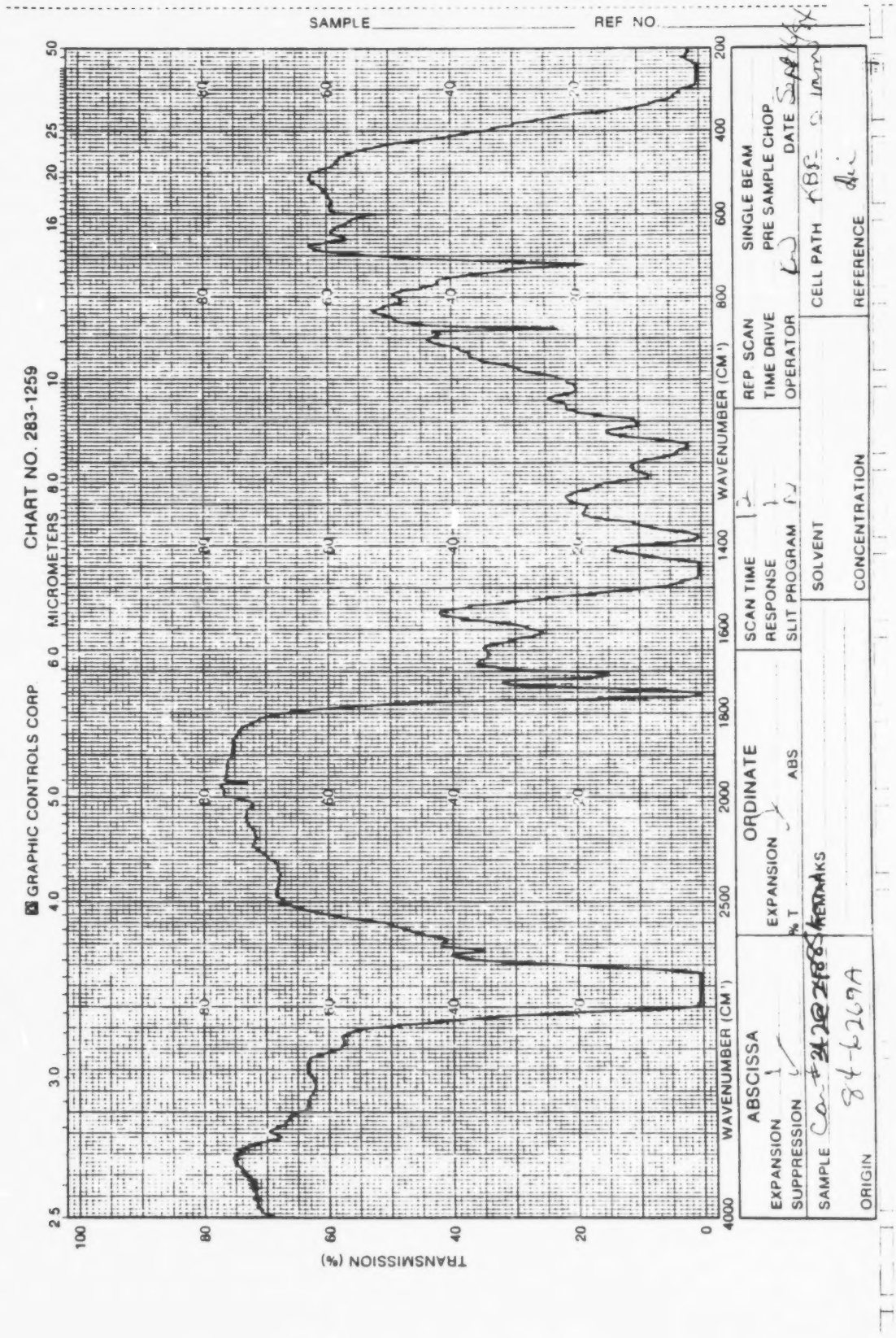
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WAVENUMBER (CM⁻¹)
TRANSMISSION (%)
ABSCISSA
EXPANSION
SUPPRESSION
ORIGIN
ORDINATE
EXPANSION
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ABS
SCAN TIME
RESPONSE
SLIT PROGRAM
REP SCAN
TIME DRIVE
OPERATOR
SINGLE BEAM
PRE SAMPLE CHOP
DATE
CELL PATH
REFERENCE
SAMPLE
REMARKS
SOLVENT
CONCENTRATION
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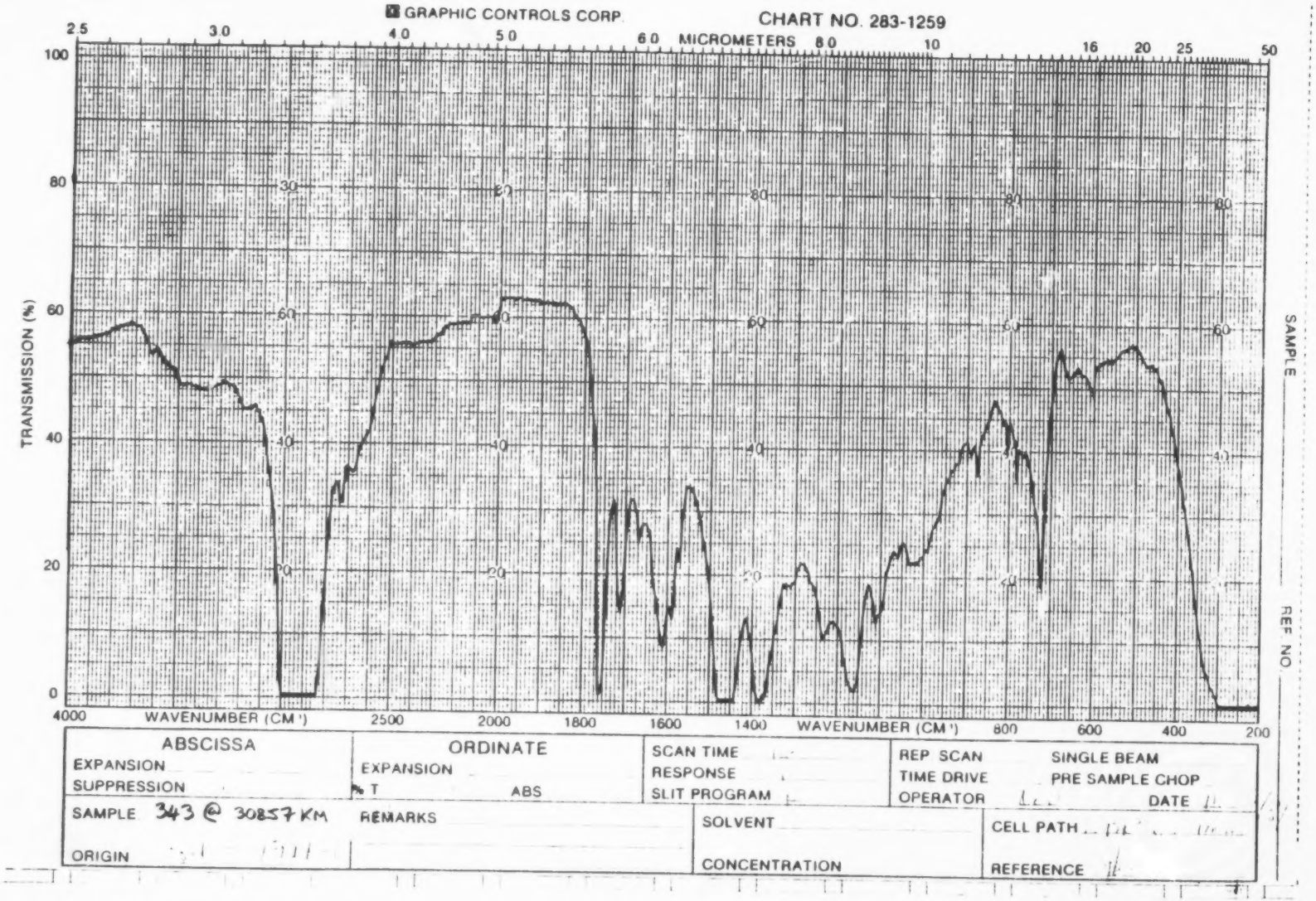
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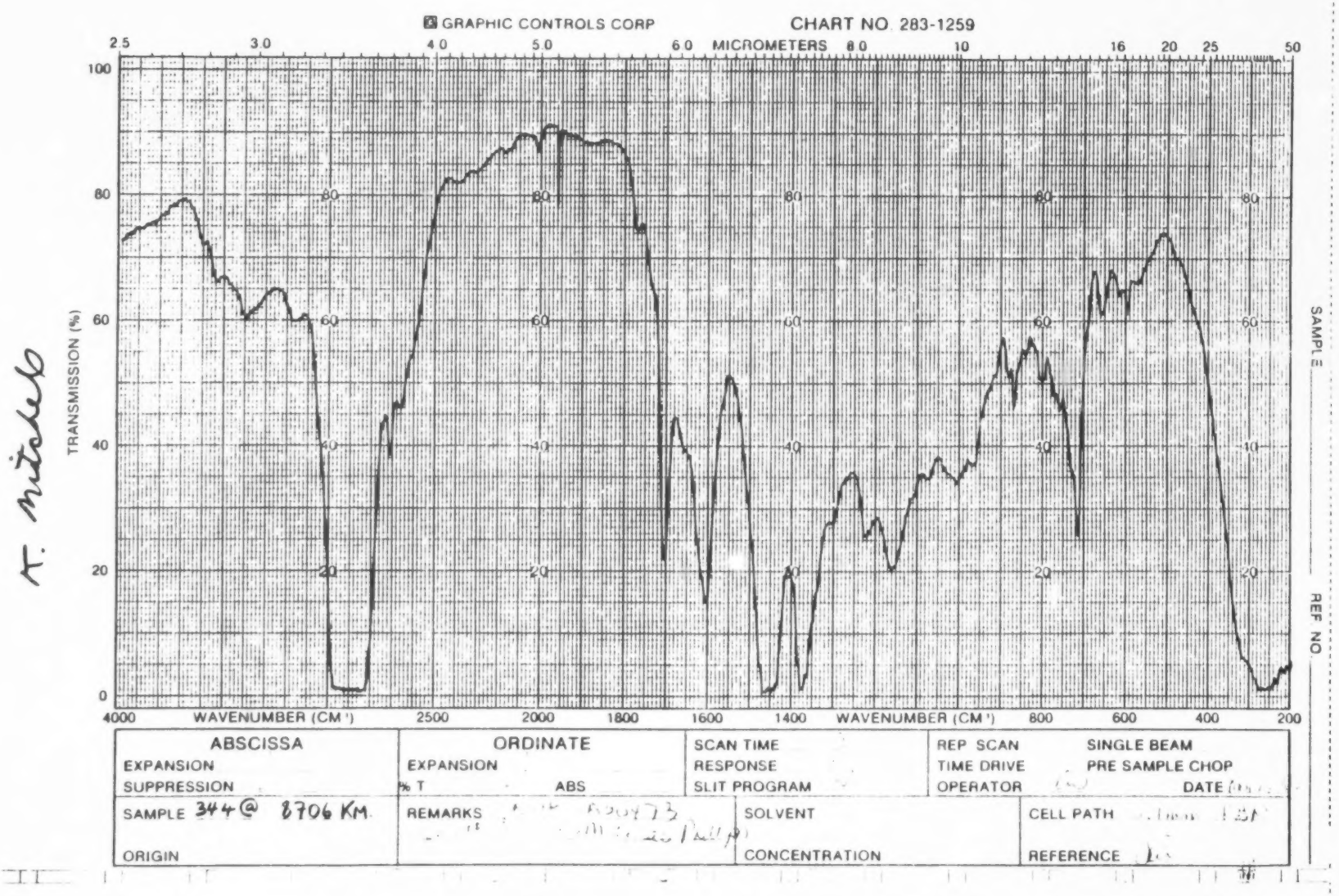
CHART NO. 283-1259
MICROMETERS
TRANSMISSION (%)
WAVENUMBER (CM⁻¹)
WAVENUMBER (CM⁻¹)
SAMPLE
REF NO.
ABSCISSA
EXPANSION
SUPPRESSION
ORDINATE
EXPANSION
T
ABS
SCAN TIME
RESPONSE
SLIT PROGRAM
REP SCAN
SINGLE BEAM
TIME DRIVE
PRE SAMPLE CHOP
OPERATOR
DATE
SAMPLE 343 @ 30857 KM
REMARKS
ORIGIN
SOLVENT
CONCENTRATION
CELL PATH
REFERENCE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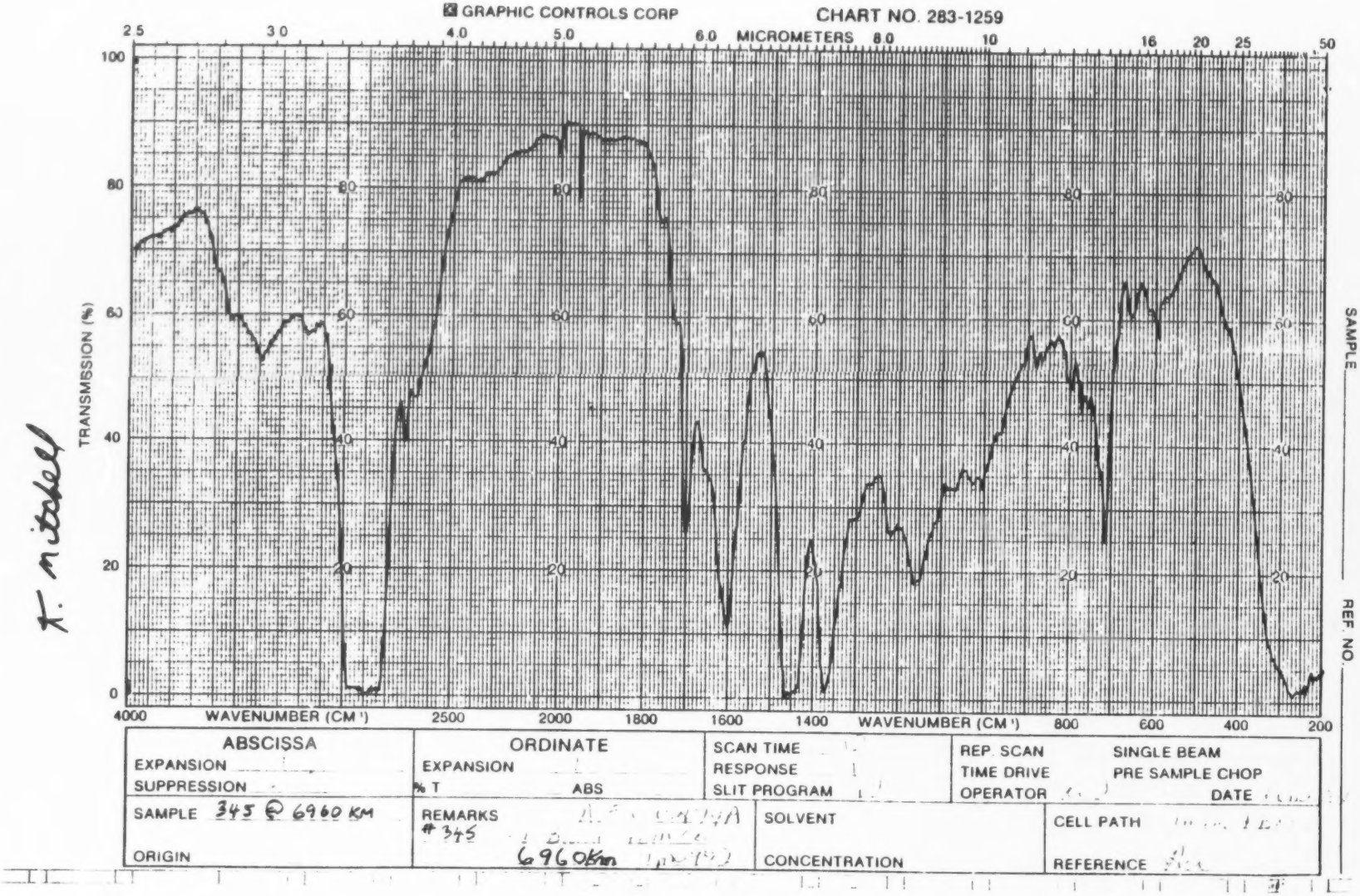
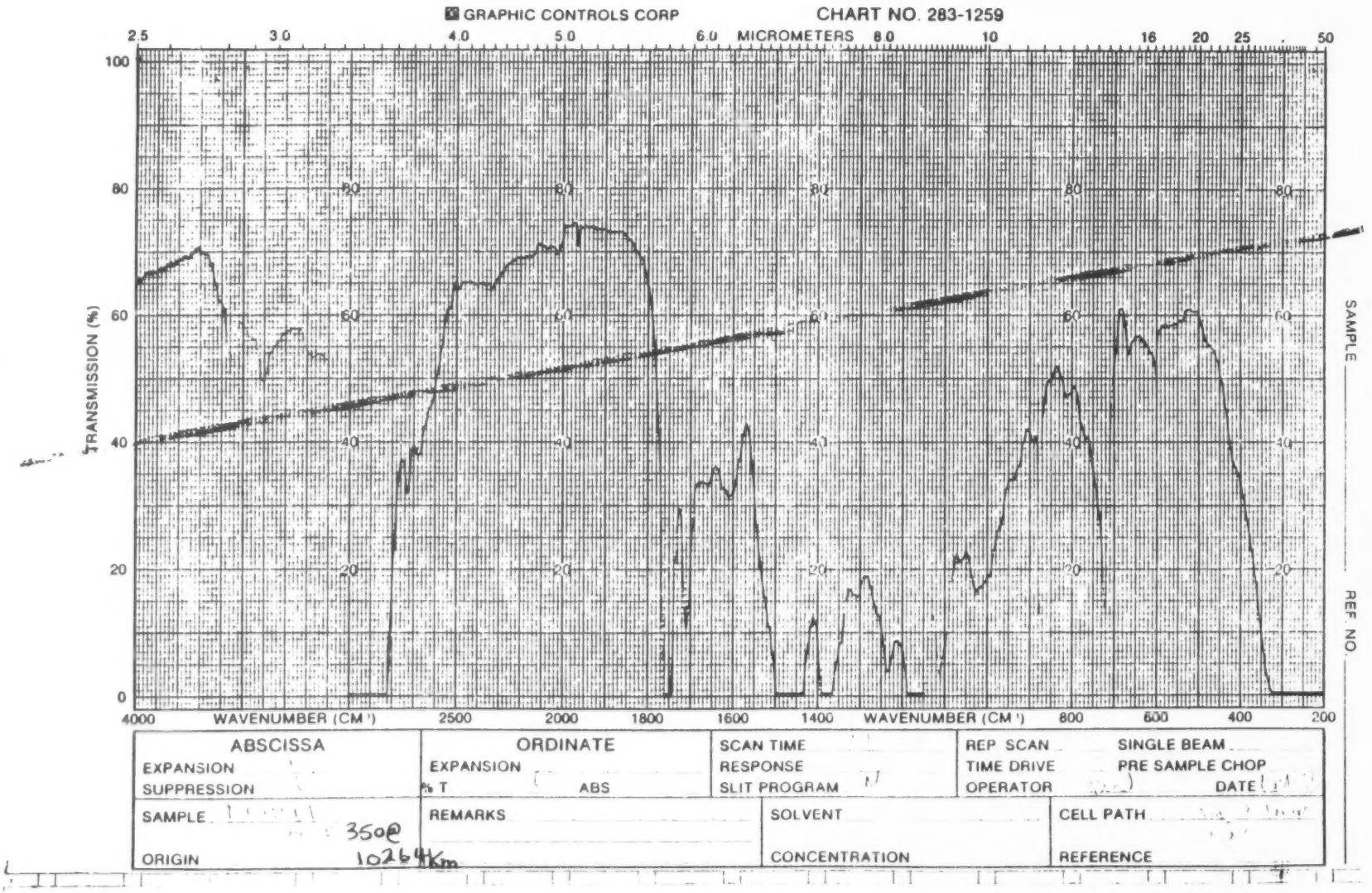
2.5 3.0 4.0 5.0 6.0 MICROMETERS 8.0 10 16 20 25 50
100 80 60 40 20 0
TRANSMISSION (%)
4000 WAVENUMBER (CM⁻¹) 2500 2000 1800 1600 1400 WAVENUMBER (CM⁻¹) 800 600 400 200
SAMPLE
REF NO.
ABSCISSA
EXPANSION
SUPPRESSION
ORDINATE
EXPANSION
% T ABS
SCAN TIME
RESPONSE
SLIT PROGRAM
REP SCAN
TIME DRIVE
OPERATOR
SINGLE BEAM
PRE SAMPLE CHOP
DATE
SAMPLE 344 @ 8706 KM
ORIGIN
REMARKS
SOLVENT
CONCENTRATION
CELL PATH
REFERENCE

T. mitsuko


GRAPHIC CONTROLS CORP
CHART NO. 283-1259
2.5 3.0 4.0 5.0 6.0 MICROMETERS 8.0 10 16 20 25 50
100 80 60 40 20 0
TRANSMISSION (%)
4000 WAVENUMBER (CM⁻¹) 2500 2000 1800 1600 1400 WAVENUMBER (CM⁻¹) 800 600 400 200
SAMPLE
REF. NO.
ABSCISSA
EXPANSION
SUPPRESSION
ORDINATE
EXPANSION
% T ABS
SCAN TIME
RESPONSE
SLIT PROGRAM
REP. SCAN
TIME DRIVE
OPERATOR
SINGLE BEAM
PRE SAMPLE CHOP
DATE
SAMPLE 345 @ 6960 KM
ORIGIN
REMARKS
#345
6960km
SOLVENT
CONCENTRATION
CELL PATH
REFERENCE

T. mitchell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2.5 3.0 4.0 5.0 6.0 MICROMETERS 8.0 10 16 20 25 50
100 80 60 40 20 0
%TRANSMISSION (%)
4000 WAVENUMBER (CM⁻¹) 2500 2000 1800 1600 1400 WAVENUMBER (CM⁻¹) 800 600 400 200
SAMPLE
REF. NO.
ABSCISSA
EXPANSION
SUPPRESSION
ORDINATE
EXPANSION
% T ABS
SCAN TIME
RESPONSE
SLIT PROGRAM
REP SCAN
TIME DRIVE
OPERATOR
SINGLE BEAM
PRE SAMPLE CHOP
DATE
SAMPLE
ORIGIN
3500
1026 Km
REMARKS
SOLVENT
CONCENTRATION
CELL PATH
REFERENCE

APPENDIX E/ USED-OIL ANALYSIS RESULT INTREPRETATION

Test	Results "Warning Limits"	"Median"	"90%ile"	"Typical"	Components
TBN	50% drop	-	-	-	
Viscosity @100°C	25% drop	-	-	-	
Pentane Insols, % by mass	>1.5	-	-	-	
Al, ppm	>40	19	15	-	Pistons
Cr	>40	6.4	-	-	Rings
Cu	>40	22	35	-	Bearings, Bushings
Fe	>100	47	75	-	Cylinders
Pb	>40	-	-	-	Bearings
Si	>20	18	17	20	Dirt
Source	1	2	3	4	

- All above data refers to used oil condition at drain.

Sources: 1/ "Testing Used Engine Oils", Chevron Research Co., 1983

2/ SAE Paper 77-642 (on Diesel Engines)

3/ SAE Paper 73-745 (on Diesel Engines)

4/ Fuels and Lubes Magazine, Sept./Oct., 1980

APPENDIX F/ EXHAUST EMISSIONS AND FUEL CONSUMPTION

***** 1975 CVS & HWFET EMISSION TEST RESULTS *****

CAR YEAR,MAKE,MODEL,DISPL,CARB = 83 FORD ESCORT
CAR NO. OR LIC. NO.(CATALYST?) = 339
DESCRIPTION OF TEST = EMISSIONS 25 C
DATE OF TEST + OTHER INFO = 83.11.04 MEOH 10 SNL/S 3ME
DYNAMOMETER RUN NUMBER(S) = 6253-4-5-6
DYNO WINDAGE SETTING = 1.87
DYNO INERTIA SETTING = -0.8
FUEL DENSITY (GM/ML) = 0.7809
FUEL-PERCENT CARBON = 40.16
ODOMETER READING KM = 0.0
VEHICLE INERTIA WEIGHT KG = 1077.3
DYNO HP (INDICATED) AT 80 KM/H = 6.0
ACTUAL URBAN DIST. KM = 17.89
ACTUAL HIGHWAY DIST. KM = 16.45
AMBIENT BAROMETRIC PRESSURE = 29.80
SPECIFIC HUMIDITY
KG MOISTURE/KG DRY AIR = 0.0039
RELATIVE HUMIDITY PERCENT = 20.470

***** MASS EMISSIONS (GRAMS PER KILOMETRE) *****

TRANSIENT COLD		STABILIZED COLD		TRANSIENT HOT	
HC =	0.35	HC =	0.20	HC =	0.38
CO =	5.40	CO =	0.26	CO =	5.13
NOX =	0.41	NOX =	0.22	NOX =	0.35
CO2 =	172.41	CO2 =	186.47	CO2 =	150.29

****** TEST SUMMARY (WEIGHTED AND CORRECTED GRAMS/KM) ******

CITY	HC =	0.28	CO =	2.65	NOX =	0.29	CO2 = 173.7
HIGHWAY	HC =	0.05	CO =	0.13	NOX =	0.31	CO2 = 121.7

********* FUEL CONSUMPTION DATA *********

	FUEL CONSUMED IN ML	ACTUAL DISTANCE TRAVELLED IN KM
TRANS COLD =	858.50	5.79
STAB COLD =	990.40	6.31
TRANS HOT =	783.58	5.79
HIGHWAY =	1724.93	16.45

********** FUEL CONSUMPTION **********

* CVS C/H *

	CARBON BALANCE L/100 KM	DIRECT MEASURE L/100 KM	DIFFERENCE PERCENT
TRANS COLD =	15.84	14.83	-6.85
STAB COLD =	16.32	15.70	-4.01
TRANS HOT =	13.89	13.53	-2.64
WEIGHTED CVS =	15.56	14.93	-4.26
UNWEIGHTED =	15.38	14.71	-4.53
HIGHWAY =	10.62	10.49	-1.32
COMBINED RATING =	13.34	12.93	-3.18

* STEADY STATES *

L/100 KM AT 60 KM/H = 7.26
L/100 KM AT 100 KM/H = 11.42

***** 1975 CVS & HWFET EMISSION TEST RESULTS *****

CAR YEAR,MAKE,MODEL,DISPL,CARB = 83 FORD ESCORT
CAR NO. OR LIC. NO.(CATALYST?) = 340
DESCRIPTION OF TEST = EMISSIONS 25 C
DATE OF TEST + OTHER INFO = 83.11.10 MEOH 85%/15%ME
DYNAMOMETER RUN NUMBER(S) = 6225-6-7-8
DYNO WINDAGE SETTING = 1.80
DYNO INERTIA SETTING = -0.8
FUEL DENSITY (GM/ML) = 0.7809
FUEL-PERCENT CARBON = 40.16
ODOMETER READING KM = 0.0
VEHICLE INERTIA WEIGHT KG = 1077.3
DYNO HP (INDICATED) AT 80 KM/H = 6.0
ACTUAL URBAN DIST. KM = 18.01
ACTUAL HIGHWAY DIST. KM = 16.50
AMBIENT BAROMETRIC PRESSURE = 29.59
SPECIFIC HUMIDITY
KG MOISTURE/KG DRY AIR = 0.0055
RELATIVE HUMIDITY PERCENT = 28.692

***** MASS EMISSIONS (GRAMS PER KILOMETRE) *****

TRANSIENT COLD		STABILIZED COLD		TRANSIENT HOT	
HC =	0.54	HC =	0.12	HC =	0.28
CO =	5.02	CO =	0.32	CO =	1.44
NOX =	0.43	NOX =	0.19	NOX =	0.31
CO2 =	186.08	CO2 =	184.90	CO2 =	158.14

****** TEST SUMMARY (WEIGHTED AND CORRECTED GRAMS/KM) ******

CITY	HC =	0.25	CO =	1.59	NOX =	0.27	CO2 = 177.2
HIGHWAY	HC =	0.03	CO =	0.14	NOX =	0.23	CO2 = 124.2

********* FUEL CONSUMPTION DATA *********

	FUEL CONSUMED IN ML	ACTUAL DISTANCE TRAVELLED IN KM
TRANS COLD =	1140.61	5.82
STAB COLD =	976.44	6.38
TRANS HOT =	783.84	5.81
HIGHWAY =	1692.15	16.50

********** FUEL CONSUMPTION **********

* CVS C/H *

	CARBON BALANCE L/100 KM	DIRECT MEASURE L/100 KM	DIFFERENCE PERCENT
TRANS COLD =	17.04	19.60	13.07
STAB COLD =	16.17	15.30	-5.68
TRANS HOT =	14.04	13.49	-4.06
WEIGHTED CVS =	15.77	15.69	-0.49
UNWEIGHTED =	15.76	16.11	2.14
HIGHWAY =	10.84	10.26	-5.71
COMBINED RATING =	13.55	13.25	-2.31

* STEADY STATES *

L/100 KM AT 60 KM/H = 7.89
L/100 KM AT 100 KM/H = 11.29

***** 1975 CVS & HWFET EMISSION TEST RESULTS *****

CAR YEAR,MAKE,MODEL,DISPL,CARB = FORD ESCORT
CAR NO. OR LIC. NO.(CATALYST?) = 339
DESCRIPTION OF TEST = EMISSIONS 250
DATE OF TEST + OTHER INFO = 84.09.25 MEOH 10SNL/5DME
DYNAMOMETER RUN NUMBER(S) = 6607-8-9-10
DYNO WINDAGE SETTING = 1.79
DYNO INERTIA SETTING = -0.5
FUEL DENSITY (GM/ML) = 0.7861
FUEL-PERCENT CARBON = 40.28
ODOMETER READING KM = 20140.0
VEHICLE INERTIA WEIGHT KG = 1077.3
DYNO HP (INDICATED) AT 80 KM/H = 6.0
ACTUAL URBAN DIST. KM = 17.89
ACTUAL HIGHWAY DIST. KM = 16.48
AMBIENT BAROMETRIC PRESSURE = 29.74
SPECIFIC HUMIDITY
KG MOISTURE/KG DRY AIR = 0.0155
RELATIVE HUMIDITY PERCENT = 76.950

***** MASS EMISSIONS (GRAMS PER KILOMETRE) *****

TRANSIENT COLD		STABILIZED COLD		TRANSIENT HOT	
HC =	0.63	HC =	0.30	HC =	1.28
CO =	6.55	CO =	0.60	CO =	9.41
NOX =	0.36	NOX =	0.34	NOX =	0.50
CO2 =	181.46	CO2 =	175.36	CO2 =	154.46

****** TEST SUMMARY (WEIGHTED AND CORRECTED GRAMS/KM) ******

CITY	HC =	0.64	CO =	4.23	NOX =	0.39	CO2 = 181.4
HIGHWAY	HC =	0.16	CO =	0.20	NOX =	0.34	CO2 = 130.1

********* FUEL CONSUMPTION DATA *********

	FUEL CONSUMED IN ML	ACTUAL DISTANCE TRAVELLED IN KM
TRANS COLD =	976.85	5.79
STAB COLD =	1032.57	6.32
TRANS HOT =	852.44	5.78
HIGHWAY =	1768.60	16.48

************ FUEL CONSUMPTION ************

* CVS C/H *

	CARBON BALANCE L/100 KM	DIRECT MEASURE L/100 KM	DIFFERENCE PERCENT
TRANS COLD =	16.71	16.87	0.98
STAB COLD =	17.01	16.34	-4.09
TRANS HOT =	14.94	14.75	-1.33
WEIGHTED CVS =	16.38	16.01	-2.30
UNWEIGHTED =	16.24	16.00	-1.53
HIGHWAY =	11.29	10.73	-5.16
COMBINED RATING =	14.09	13.64	-3.31

* STEADY STATES *

L/100 KM AT 60 KM/H = 8.34
L/100 KM AT 100 KM/H = 10.99

***** 1975 CVS & HWFET EMISSION TEST RESULTS *****

CAR YEAR,MAKE,MODEL,DISPL,CARB = FORD ESCORT
CAR NO. OR LIC. NO.(CATALYST?) = 339
DESCRIPTION OF TEST = EMISSIONS 250
DATE OF TEST + OTHER INFO = 84.09.26 MEOH 10%NL/5DME
DYNAMOMETER RUN NUMBER(S) = 6611-1-3-4
DYNO WINDAGE SETTING = 1.85
DYNO INERTIA SETTING = -0.3
FUEL DENSITY (GM/ML) = 0.7861
FUEL-PERCENT CARBON = 40.28
ODOMETER READING KM = 26213.0
VEHICLE INERTIA WEIGHT KG = 1077.3
DYNO HP (INDICATED) AT 80 KM/H = 6.0
ACTUAL URBAN DIST. KM = 17.88
ACTUAL HIGHWAY DIST. KM = 16.47
AMBIENT BAROMETRIC PRESSURE = 30.06
SPECIFIC HUMIDITY
KG MOISTURE/KG DRY AIR = 0.0076
RELATIVE HUMIDITY PERCENT = 38.251

***** MASS EMISSIONS (GRAMS PER KILOMETRE) *****

TRANSIENT COLD		STABILIZED COLD		TRANSIENT HOT	
HC =	0.79	HC =	0.38	HC =	0.77
CO =	7.97	CO =	0.57	CO =	7.05
NOX =	0.32	NOX =	0.26	NOX =	0.38
CO2 =	182.54	CO2 =	201.56	CO2 =	153.97

****** TEST SUMMARY (WEIGHTED AND CORRECTED GRAMS/KM) ******

CITY	HC =	0.57	CO =	3.86	NOX =	0.31	CO2 = 184.7
HIGHWAY	HC =	0.12	CO =	0.13	NOX =	0.27	CO2 = 128.0

********** FUEL CONSUMPTION DATA **********

	FUEL CONSUMED IN ML	ACTUAL DISTANCE TRAVELLED IN KM
TRANS COLD =	962.73	5.78
STAB COLD =	1025.95	6.31
TRANS HOT =	835.01	5.79
HIGHWAY =	1786.41	16.47

************ FUEL CONSUMPTION ************

* CVS C/H *

	CARBON BALANCE L/100KM	DIRECT MEASURE L/100KM	DIFFERENCE PERCENT
TRANS COLD =	17.03	16.66	-2.27
STAB COLD =	17.56	16.26	-8.00
TRANS HOT =	14.44	14.42	-0.14
WEIGHTED CVS =	16.60	15.84	-4.81
UNWEIGHTED =	16.38	15.79	-3.73
HIGHWAY =	11.09	10.85	-2.22
COMBINED RATING =	14.12	13.59	-3.88

* STEADY STATES *

L/100KM AT 60 KM/H = 8.42
L/100KM AT 100 KM/H = 11.23

CAR YEAR,MAKE,MODEL,DISPL,CARB = 83 FORD ESCORT
CAR NO. OR LIC. NO.(CATALYST?) = 340
DESCRIPTION OF TEST = EMISSIONS 250
DATE OF TEST + OTHER INFO = 84.10.02 MEOH 10 SAE/5 DME
DYNAMOMETER RUN NUMBER(S) = 6619-20-1-2
DYNO WINDAGE SETTING = 1.88
DYNO INERTIA SETTING = -0.5
FUEL DENSITY (GM/ML) = 0.7841
FUEL-PERCENT CARBON = 40.28
ODOMETER READING KM = *******
VEHICLE INERTIA WEIGHT KG = 1077.3
DYNO HP (INDICATED) AT 80 KM/H = 6.0
ACTUAL URBAN DIST. KM = 17.95
ACTUAL HIGHWAY DIST. KM = 16.55
AMBIENT BAROMETRIC PRESSURE = 30.02
SPECIFIC HUMIDITY
KG MOISTURE/KG DRY AIR = 0.0065
RELATIVE HUMIDITY PERCENT = 32.666

***** MASS EMISSIONS (GRAMS PER KILOMETRE) *****

TRANSIENT COLD		STABILIZED COLD		TRANSIENT HOT	
HC =	1.09	HC =	0.72	HC =	1.30
CO =	6.92	CO =	10.48	CO =	9.95
NOX =	0.42	NOX =	0.34	NOX =	0.48
CO2 =	175.82	CO2 =	165.38	CO2 =	140.68

****** TEST SUMMARY (WEIGHTED AND CORRECTED GRAMS/KM) ******

CITY	HC =	0.95	CO = 9.60	NOX =	0.40	CO2 =	160.8
HIGHWAY	HC =	0.17	CO = 0.27	NOX =	0.45	CO2 =	116.8

********* FUEL CONSUMPTION DATA *********

	FUEL CONSUMED IN ML	ACTUAL DISTANCE TRAVELLED IN KM
TRANS COLD =	932.96	5.80
STAB COLD =	916.17	6.33
TRANS HOT =	821.78	5.82
HIGHWAY =	1617.99	16.55

********** FUEL CONSUMPTION **********

* CVS C/H *

	CARBON BALANCE L/100 KM	DIRECT MEASURE L/100 KM	DIFFERENCE PERCENT
TRANS COLD =	16.40	16.09	-1.93
STAB COLD =	15.88	14.47	-9.68
TRANS HOT =	13.83	14.12	2.03
WEIGHTED CVS =	15.43	14.71	-4.88
UNWEIGHTED =	15.38	14.89	-3.38
HIGHWAY =	10.15	9.78	-3.84
COMBINED RATING =	13.05	12.49	-4.52

* STEADY STATES *

L/100 KM AT 60 KM/H = 7.55
L/100 KM AT 100 KM/H = 10.63

***** 1975 CVS & HWFET EMISSION TEST RESULTS *****

CAR YEAR,MAKE,MODEL,DISPL,CARB = 83 FORD ESCORT
CAR NO. OR LIC. NO.(CATALYST?) = 340
DESCRIPTION OF TEST = EMISSIONS 250
DATE OF TEST + OTHER INFO = 84.10.03 MEOH 10 SNL/5 DME
DYNAMOMETER RUN NUMBER(S) = 6623-4-5-6
DYNO WINDAGE SETTING = 1.88
DYNO INERTIA SETTING = -0.5
FUEL DENSITY (GM/ML) = 0.7841
FUEL-PERCENT CARBON = 40.28
ODOMETER READING KM = 26398.0
VEHICLE INERTIA WEIGHT KG = 1077.3
DYNO HP (INDICATED) AT 80 KM/H = 6.0
ACTUAL URBAN DIST. KM = 18.01
ACTUAL HIGHWAY DIST. KM = 16.56
AMBIENT BAROMETRIC PRESSURE = 29.46
SPECIFIC HUMIDITY
KG MOISTURE/KG DRY AIR = 0.0056
RELATIVE HUMIDITY PERCENT = 27.679

***** MASS EMISSIONS (GRAMS PER KILOMETRE) *****

TRANSIENT COLD		STABILIZED COLD		TRANSIENT HOT	
HC =	0.85	HC =	0.64	HC =	1.05
CO =	7.46	CO =	10.70	CO =	10.02
NOX =	0.52	NOX =	0.35	NOX =	0.45
CO2 =	170.33	CO2 =	162.21	CO2 =	140.02

****** TEST SUMMARY (WEIGHTED AND CORRECTED GRAMS/KM) ******

CITY	HC =	0.80	CO =	9.85	NOX =	0.41	CO2 = 157.8
HIGHWAY	HC =	0.13	CO =	0.19	NOX =	0.46	CO2 = 117.9

********* FUEL CONSUMPTION DATA *********

	FUEL CONSUMED IN ML	ACTUAL DISTANCE TRAVELLED IN KM
TRANS COLD =	901.67	5.83
STAB COLD =	925.45	6.37
TRANS HOT =	815.55	5.81
HIGHWAY =	1633.51	16.56

********** FUEL CONSUMPTION **********

* CVS C/H *

	CARBON BALANCE L/100 KM	DIRECT MEASURE L/100 KM	DIFFERENCE PERCENT
TRANS COLD =	15.93	15.47	-2.99
STAB COLD =	15.61	14.53	-7.45
TRANS HOT =	13.72	14.04	2.28
WEIGHTED CVS =	15.16	14.59	-3.92
UNWEIGHTED =	15.10	14.67	-2.91
HIGHWAY =	10.23	9.86	-3.70
COMBINED RATING =	12.94	12.46	-3.85

* STEADY STATES *

L/100 KM AT 60 KM/H = 7.62
L/100 KM AT 100 KM/H = 10.37

***** 1975 CVS & HWFET EMISSION TEST RESULTS *****

CAR YEAR,MAKE,MODEL,DISPL,CARB = FORD ESCORT
CAR NO. OR LIC. NO.(CATALYST?) = 340
DESCRIPTION OF TEST = EMISSIONS 250 NEW CATALYST + DIVERTER VALVE
DATE OF TEST + OTHER INFO = 84.10.10 M60H 10 SNL/5DME
DYNAMOMETER RUN NUMBER(S) = 6631-2-3-4
DYNO WINDAGE SETTING = 1.775
DYNO INERTIA SETTING = -0.5
FUEL DENSITY (GM/ML) = 0.7861
FUEL-PERCENT CARBON = 40.28
ODOMETER READING KM = *******
VEHICLE INERTIA WEIGHT KG = 1077.3
DYNO HP (INDICATED) AT 80 KM/H = 6.0
ACTUAL URBAN DIST. KM = 17.97
ACTUAL HIGHWAY DIST. KM = 16.51
AMBIENT BAROMETRIC PRESSURE = 30.20
SPECIFIC HUMIDITY
KG MOISTURE/KG DRY AIR = 0.0106
RELATIVE HUMIDITY PERCENT = 53.191

***** MASS EMISSIONS (GRAMS PER KILOMETRE) *****

TRANSIENT COLD		STABILIZED COLD		TRANSIENT HOT	
HC =	0.62	HC =	0.44	HC =	0.87
CO =	6.63	CO =	6.59	CO =	6.91
NOX =	0.60	NOX =	0.29	NOX =	0.50
CO2 =	172.51	CO2 =	169.82	CO2 =	141.35

****** TEST SUMMARY (WEIGHTED AND CORRECTED GRAMS/KM) ******

CITY	HC =	0.59	CO =	6.69	NOX =	0.41	CO2 = 162.6
HIGHWAY	HC =	0.13	CO =	0.19	NOX =	0.48	CO2 = 116.3

********** FUEL CONSUMPTION DATA **********

	FUEL CONSUMED IN ML	ACTUAL DISTANCE TRAVELLED IN KM
TRANS COLD =	923.93	5.82
STAB COLD =	902.68	6.34
TRANS HOT =	776.49	5.81
HIGHWAY =	1600.43	16.51

************ FUEL CONSUMPTION ************

* CVS C/H *

	CARBON BALANCE L/100 KM	DIRECT MEASURE L/100 KM	DIFFERENCE PERCENT
TRANS COLD =	15.94	15.88	-0.42
STAB COLD =	15.65	14.24	-9.95
TRANS HOT =	13.36	13.36	0.03
WEIGHTED CVS =	15.09	14.34	-5.25
UNWEIGHTED =	15.01	14.49	-3.59
HIGHWAY =	10.09	9.69	-4.10
COMBINED RATING =	12.84	12.25	-4.84

* STEADY STATES *

L/100 KM AT 60 KM/H = 0.0